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ABSTRACT

This guide contains 67 activities dealing with various aerospace/aviation education concepts. The activities are presented in units related to physical science, earth science, and life science. In addition, there is a section related to student involvement in the space shuttle programs. The physical science unit (activities 1-23) focuses on the forces and basic principles of flight and the structure of planes and rockets. The earth science unit (activities 24-44) deals with the solar system, satellites, space probes and other topics. The life science unit (activities 45-67) focuses on the human body in space. Each activity includes information on the subject area, grade level, group size, time required, teaching strategy, type of activity, concept(s) fostered, and skills fostered. Each activity also contains objective(s), materials needed, teacher background information, instructional strategies, suggested extension activities, and a code corresponding to resources found in the appendix. Resources include films, books, and additional materials organized by topic areas. Other appendices contain lists of computer software, addresses of agencies supplying media, lists of Michigan resource centers and resource persons, a glossary, and indexes of science concepts and skills by lesson. The guide's conceptual framework and other general information are found in an introduction. (JN)

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Come With Me!

EXPLORING SCIENCE 7 - 9
THROUGH AVIATION/AEROSPACE
CONCEPTS

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Come FLY with me!

EXPLORING SCIENCE **7-9** THROUGH
AVIATION/AEROSPACE CONCEPTS

by

DAVID C. HOUSEL PH.D

&

DOREEN K.M. HOUSEL MA



MICHIGAN
AERONAUTICS COMMISSION

1984

COME FLY WITH ME!
Exploring Science 7-9
Through
Aviation/Aerospace Concepts

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Lansing, Michigan

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the Aerospace Education Council of Michigan

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It is with considerable pleasure and eagerness that we introduce to you Phase II of "Come Fly With Me!", the 7-9th grade science curriculum.

The development of this curriculum guide represents our latest endeavor to use aerospace concepts as a medium to stimulate imaginative thinking in the learning process. Humanity's age-old fascination with flight provides an incentive which can be used to promote learning and achievement. This book, like its predecessor, the K-6 curriculum, attempts to take advantage of human being's innate curiosity to provide a motivation for learning new science skills and concepts.

We invite you to come along on this journey of intellectual search and, like those children whom we are trying to inspire to new heights, become newly fascinated and re-inspired in the learning process.

PREFACE

STATE OF MICHIGAN



JAMES J. BLANCHARD, GOVERNOR

DEPARTMENT OF TRANSPORTATION

CAPITAL CITY AIRPORT LANSING, MICHIGAN 48906

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JAMES P. PITZ, DIRECTOR

TO FLY has been the dream of mankind since the beginning of time. TO Fly is the dream of each child upon discovering the beauty and freedom of soaring birds. TO FLY is to experience beauty, truth and peace. We believe each child is entitled to explore the vast sky above us; to identify with man's explorations in air and space. Children can lift from the earth with the aeronauts in the first manned balloon flight in Paris, November 21, 1793; relive the famous flight of the Wright Brothers at Kitty Hawk, December 17, 1903; be propelled into space in the Mercury, Gemini, Apollo and Skylab vehicles; and, yes, they can dream of a future home in space.

We offer COME FLY WITH ME! as a vehicle to allow the teacher to assume the role of explorer along with the students when using the sky as a classroom; to teach science through the environments of air and space.

COME FLY WITH ME! EXPLORING SCIENCE 7-9, is a continuing project of the Aerospace Education Council of Michigan, a volunteer organization of educators serving the Michigan Aeronautics Commission. Cooperation of the Department of Education has been through representation on the Council.

The Commission is grateful to Oakland University which has been supportive of the authors' endeavors in writing the book, in teacher workshops, in the extensive classroom field-testing, and in the post-pilot program revisions.

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FORWARD

"We plunk kids down with books - and bad books at that - as though science is learning to recite a lot of words. That's a shame. Science is open, active, inquiring. I would ban science text books in elementary school." That is how James Rutherford, Chief Education Officer of the American Association for the Advancement of Science recently described the current state of school science. He believes that students should be doing, collecting, pushing and pulling things, asking questions and working together, looking up information in reference books.¹

And so do Housel and Housel, the authors of this book. They believe that investigation by students - through observing, data gathering, measuring, recording, identifying, constructing, hypothesizing, interpreting - has been largely neglected in the science classroom by many teachers. In this guidebook they present a set of workshop lessons that focus on scientific principles and concepts in aviation and aerospace through investigative activities that often involve the use of everyday house-hold items as experimental equipment. The lessons are designed as resources for teachers, not as prescriptions for instructional plans or curriculum sequences.

Modest though this book of practical instruction may seem on first glance, we should pause to consider its significance in light of Rutherford's observations and the present plight of science education. On the basis of his intensive review and extensive involvement in recent assessments of school science, Robert Yager, Professor and Head of Science Education at the University of Iowa, concluded that "Teachers tend to follow the textbook closely and use it as their primary tool of instruction. There is no evidence that students ever learn science by direct experience. They rarely experiment on their own; most so-called 'laboratories' are verification exercises."² It has been estimated by Harms and Yager that a textbook is used ninety percent of the time by ninety percent of all science teachers in the U.S.³ These circumstances suggest that much of students' learning about science is indirect and vicarious. Few students have opportunities in which they can deeply engage themselves and strive to make their own sense of their own observations, perceptions and hypotheses. Rarely are they absorbed in deriving meaning from their own investigation of a science problem.

Perhaps it is because students so rarely have direct, tangible learning experiences in their science classes that they turn away from science as they progress through school. The National Assessment of Educational Progress reported from its Third Assessment of Science in 1978 that student interest in science decreases between third and seventh grade and still further between seventh and eleventh grade.⁴ Fiske reported in 1979 that after tenth grade more than fifty per cent of the nation's high school students stopped taking science classes.⁵

When visiting a junior high school last April, I asked an eighth grade student what experiments her science class had done during the school year. She replied that the teacher did not arrange for lab work "because he says it's all in the textbook." About twenty years ago in an essay on science education, David Hawkins, now an eminent MacArthur Foundation Fellow and emeritus Professor of Philosophy of the University of Colorado, cautioned against such teaching: "The letter of the discipline has too often been taken to be its substance. Here as always the letter kills, especially in the early and crucial years. The tight formulation and logical sequencing must be learned, but they cannot be learned first. They will be learned only when the knower comes to prize them for their own power of liberation and guidance. What comes first is absorption in subject matter. No one learns by being led blind along a path he cannot begin very soon to see for himself."⁶

It is absorption in the subject matter of science through investigation that the authors of this guidebook seek to make practical and feasible for teachers and students. This kind of absorption comes from being involved, from having to figure things out, from assembling equipment, from tabulating data, from trying to make sense of what's happening. To this end, the authors have designed lessons (more than one third are original) that are feasible to implement in almost any classroom. The materials and equipment are inexpensive or can be borrowed from the household or a workshop. For instance, in a lesson on "Oval Orbits" the materials needed are: a basketball, a coat hanger, two to three feet of string, a lead fishing sinker, a water pail, a thimble and a softball. Through such lessons students can achieve an understanding of scientific principles and concepts based on their own investigations. With these learnings, the authors believe, students can apply and extend their understandings: they can connect these understandings of everyday phenomena with the phenomena of flight and space - a connection fundamental to science since Issac Newton proposed in 1665-66 that the same force that keeps chairs on the floor also keeps the moon in its orbit.

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August, 1984

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4. National Assessment of Educational Progress. The third assessment of science. Denver, Colorado: National Assessment of Educational Progress. May, 1978.
5. Fiske, E. B. Science's heyday in schools is past. The New York Times, April, 1979.
6. Hawkins, D. The informed vision: An essay on science education. Daedalus, 94(3). Summer, 1965.
7. An image adapted from Rigden, J. S. The art of great science. Phi Delta Kappan, 64(1). May, 1983.

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David and Doreen Housel
Northville, Michigan
June, 1984



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SUBJECT - "Science". All activities are science oriented, though other subject areas are often integrated.

GRADE - Written for 7, 8, 9, with grade level cognitive and affective development in mind. However, many of the lessons may be appropriate for higher or lower grade level.

GROUP SIZE - Group size which will probably produce most success with this lesson. Activities will be labeled: "Individual," "Small Group" (2-7) and "Large Group" (8 or more).

TIME - Given in minutes. An approximation of the time that it should take to carefully work through an activity with a group of "average" learners.

TYPE OF ACTIVITY - Examples might be: "Student Investigation," "Teacher Presentation," "Discussion," "Experiment," or "Simulation/Game."

TEACHING STRATEGY - "Expository," "Open Discovery," or "Guided Discovery." See the Teaching Strategies section of the INTRODUCTION.

CONCEPTS - Science concept(s) are those emphasized in the lesson. Examples: "Hot air rises," "Gravity," "Orbit," or "System."

SKILLS - Basic science and complex integrated process skills emphasized in the lesson. See "A Note on Process Skills" found in the Structure and Content section of the INTRODUCTION.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Individual and Large

TIME:
2-45 minute periods

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Guided Discovery

CONCEPTS:
Lifting Body
Descent

SKILLS:
Modeling
Experimenting
Collecting Data

RESOURCES:
BK - F

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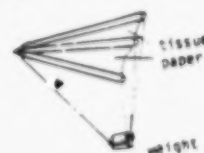
RECOVERING SPACECRAFT WITH PARAGLIDERS

Objective: To demonstrate the way paragliders work.

Materials: Seven 1/4" dowels 12 inches long; heavy tissue paper or wrapping paper; tape; scissors; knife; electric drill with a 1/8" or 1/16" bit.

Teacher Background Information: Parachutes have been used in the recovery of manned spacecraft and to slow jets landing at high speeds. The parachute systems for recovering space vehicles have been very workable but parachutes do present the problem of maneuverability. NASA has been experimenting with a paraglider which would be maneuverable and create lift. This device could be used to land space vehicles at a predetermined area.

Procedure: Using the drill, make a small hole in one end of each dowel, about 4" from the end. Using the knife, taper the ends with the holes in them. Tie the three ends together so they form a fan shape. Cut pieces of the paper to fasten over the dowels, making sure you allow some slack so the glider has two billowing sections. Tie a string to the end of each dowel and one to the front section so a weight can be tied to the strings.



Take the class outside and experiment with various weights tied to the paraglider. How much weight can it hold and still provide a safe descent? Have students discuss what variables have to be considered in constructing a paraglider.

Extension: Ask the students to construct a paraglider capable of returning an egg to the ground safely from a 30 foot height with little or no protective wrapping around the egg.

HOW TO USE THIS GUIDE

OBJECTIVES - Major cognitive and/or affective learnings expected of the students. Examples might be: "Student will know several ways to use a parachute," "Student will transcribe data to a chart," "Student will work as cooperative member of investigation team."

MATERIALS - Materials teacher and students need to complete the activity as written. A conscious effort has been made to include activities that use materials readily available or materials which can be constructed by the students. When activities may be enhanced by the use of commercially available materials, sources are listed.

TEACHER BACKGROUND INFORMATION - May be conceptual information or strategy information. It is hoped that this will be enough to get the activity started; however, if the teacher wants more information, the Resources should be of help in providing additional background material.

PROCEDURE - How to initiate the activity, a set of directions to follow and, where appropriate, suggestions for evaluation.

EXTENSIONS - Things to do that either continue an activity or modify it in some way.

RESOURCES - Resource books are noted here by "BK" followed by a letter indicating the section in which books can be found in the Book Section of the Appendices. Films are noted by "FW" followed by a number(s) and can be found in the Film and Filmstrip Section of the Appendices.



INTRODUCTION

CONCEPTUAL FRAMEWORK

The history is star-studded: Joseph and Jacques Etienne; Orville and Wilbur Wright; Robert Goddard; Charles Lindberg; Eugene A. Sanger; August Martin; Yuri Gagarin; Alan Shepard; John Glenn; Valentina Tereshkova; Neil Armstrong, Edwin Aldin and Michael Collins; Sally Ride; Guy Bluford, et al.

The technology is awesome: 13th Century Chinese rockets begin it all; 18th Century hot air balloons rise 900 meters and land 15 kilometers from their starting point; a twelve second plane flight at Kitty Hawk, N.C. in 1903 goes almost unnoticed; the first liquid propellant rocket is fired in Massachusetts in 1926 and, in 1927, the world celebrates the 3,610 mile journey across the Atlantic of the Spirit of St. Louis; a 184 pound satellite named Sputnik is launched into space in 1957; Apollo 11 lands on the moon with three Americans who walk its surface in 1969; Skylab 2 orbits for 672 hours in 1973; Americans hook up with the Russians in space during Apollo-Soyuz in 1975; Viking 1 and 2 land on Mars in 1976; in 1979, Voyager 1 and 2 fly by Jupiter; the Space Shuttle orbiter Columbia becomes the first reusable spacecraft in 1981; and, in 1983, Pioneer 10 passes the orbit of Neptune on its journey out of our solar system for worlds beyond.

The results are spectacular: two-thirds of the world's telephone communication and nearly all intercontinental television is now transmitted by spacecraft in synchronous orbit 22,300 miles above the equator; weather satellites track storms and give us readings on cloud cover, wind, temperature and pressure; our Landsat satellite provides images of the Earth, mapping the United States every eighteen days, detecting changes in surface features from urban sprawl to insect infestation, from deforestation to water pollution; Nimbus 7 spacecraft scans the oceans and provides invaluable navigational assistance; monitors are created for ambulance and intensive care unit patients, cardiac pacemakers and insulin pumps are manufactured, laser beam scalpels

are produced largely because the space program has provided us with the technology to do so.

The future is wide open: giant deployable space antennas; space platforms for telescopes, communication dishes and air pollution sensors; construction in space; the mining of resources on other planets; solar power space stations; and, most exciting perhaps, space colonies and cities.

The concepts of flying and of space can no longer be relegated to the realm of science fiction. They are, instead, essential components of our lives and an understanding of them will be even more vital to our students' lives. Students already know this and are highly motivated both by the inherent excitement of aerospace and the knowledge that it is truly meaningful to their futures.

In addition, aerospace concepts provide us with so many, as yet, unanswered questions. The need to know - the need to sort out what is so - is an innate human characteristic and the teacher can use that need well here. However, the need to know does not automatically include the way to know and, in this, the teacher's role is crucial. As good science teaching stresses the "way to know," so does this guide. Indeed, it is perhaps the basic foundation of its construction.

An Infusion Model

Teachers are inundated today with programs "vital" to their students and the Guide recognizes and appreciates the difficulty of adding another. Because of this, the activities are designed to be infused into the existing curricula in various ways. If, for example, a teacher is expected to teach astronomy, a number of activities from the Guide could be pulled and used as a unit. Or, if a teacher wished to do a unit on the human body, she might use some of the activities that deal with the body's needs in a foreign environment, such as space, to get to those concepts. If appropriate, the teacher can use material from all three units and put together a "Space Unit" that touches on all three sciences: life, physical and earth. Or, of course, those teachers who are restricted to teaching a physical, earth or life science class can use the activities appropriate to their field.

Goals

The Guide provides activities with the following overall goals in mind: 1.) activities should provide students with aerospace experiences which will help them advance their science skills through the transition from concrete operations to abstract thinking;

2.) activities should provide students with information about aviation and aerospace and guide them to people and places where they can gather additional information;

3.) activities should provide students with experiences that will

not dull their natural curiosity but will expand and enhance that curiosity;

4.) activities should provide students with the opportunity to apply science concepts under consideration in meaningful and enlightening ways.

Conceptual Themes

Additional concepts also tend to find their way into the Guide. For example, the notion of interrelationships is considered in many of the activities. The importance of understanding the idea of systems and subsystems is stressed as is the importance of understanding the interrelationships between people and things and between people and people.

Also, there is a focus on change and adaptation in the experiences found in the Guide. It is significant that students know there are certain forces in the environment which act on things and that some of these forces are immutable. Many of these provide us with our laws of science. Other forces are alterable and knowing how to change them can provide students with more control over their environment. It is vital for students to understand both kinds of forces and to be able to differentiate between them.

Another idea found throughout the activities of the Guide is that science skills are life and life-time skills. Science is the very core of discovering what life is about and the activities foster skills that students will use, not only in the classroom, but in their various endeavors to ascertain what life is.

As a correlate to the above, the Guide deals with the importance of problem solving skills. It is significant in this day of rapidly changing technology, that students know how to learn and how to solve problems rather than learn only the "right" answers to specific questions posed by others. The Guide attempts to provide students with the chance to practice some creative problem solving techniques and to apply those techniques to meaningful situations.

Finally, it is important that young people never lose their sense of appreciation for the benefits of exploration. What is meant here is an appreciation, not only for the very real, practical and immediate benefits of exploration, but a cherishing of the need to know about what is unknown for the sake of the search itself. The innate need to know may be something that youngsters bring to our classrooms but it can be thwarted so easily by those who disallow dreaming in the classroom or by those who would temper children's curiosity with matters more practical and "down to earth." This guide fosters dreaming; equally important, it gives students some of the tools necessary to making dreams a reality.

STRUCTURE AND CONTENT

The Guide consists of three aerospace science units for the junior high level related to Physical Science, Earth Science and Life Science. In addition, there is a section related to the Student Space Shuttle Involvement Program.

The Physical Science unit focuses on the forces of flight, the basic principles of flight and an understanding of the structure of planes and rockets. The Earth Science unit deals with an understanding of the Solar System, the importance of satellites and space probes in gaining environmental information, the interrelatedness of human beings with the environment and the science skills and techniques necessary to obtain and interpret scientific data. The life science unit focuses on an understanding of the body living in space and the conditions necessary for life, as we know it, in space. The Space Shuttle Student Involvement Program section details how the program works, offers a synopsis of past National Winners' projects and provides additional activities related to the Space Shuttle.

A Note on Process Skills

The process skills of science are the basic skills necessary to effectively inquire and are used by students to gather and analyze information in order to build conceptual understandings of their world. The various process skills noted in the activities are those deemed most important to the activity. Frequently, an activity will serve to develop more than one process skill.

The definitions for the process skills are given in the following:

Observing Using the senses to gather data from one's environment.

Ordering Placing objects, ideas or events in a logical series based on their characteristics.

Classifying Placing objects, ideas or events in categories based on their characteristics.

Data Collection and Recording Systematic methods of recording and displaying information concerning the environment.

Measuring Using a system of references and standards in order to determine quantitative characteristics of objects or events.

Inferring Interpreting data.

Predicting Forecasting of phenomena based on observation and inference.

Experimenting Conducting investigations in a scientific manner in order to derive answers to specific questions.

Constructing and Interpreting Models Representation of ideas.

Identification and Control of Variables Identifying and manipulating parts of objects or events which, when changed, make a difference in how the object or event behaves.

Hypothesizing Constructing questions which can be evaluated by observation, inference or experiment.

A Note on Concepts

"Concepts are words or phrases, that is, labels, which represent the essential characteristics or attributes of a class of objects, events, situations or systems ... An understanding of concepts, according to Jerome Bruner, 1.) reduces the complexity of the environment and therefore, 2.) reduces the necessity of constant learning."¹

It is important that students know and understand a number of aerospace concepts if they are to live comfortably and fully in a future that will expect them not only to apply many of the concepts in their daily lives, but will also ask them to analyze and evaluate the need for and uses of this "new" technology.

Students will have had an acquaintance with many of the aviation and space concepts, of course, without formal instruction in them. Indeed, students will come to aerospace activities with a variety of background experiences on which to draw. However, many of the concepts inherent in this area of science are not learned thoroughly or accurately when the student is left to figure out for himself or herself just what is involved

1. Porter, L., et al. The skills infusion laboratory handbook for inservice facilitators. Berkley, MI: Skills Diffusion Laboratory, Berkley Schools, 1981.

in a given concept. Such concepts as flight, spacecraft, air resistance, relativity, hyperspeed, interaction, jet propulsion, or living in space should be part of the ongoing curriculum that is formally taught in schools.

One way to teach students various aerospace concepts is outlined in "Concept Attainment Strategies" found in the Teaching Strategies portion of the Introduction to this guide.

A Note on Problem Solving

Problem solving, or scientific thinking, is a complex ability made up of several identifiable elements: the ability to formulate problems, to analyze problems, to obtain information from a variety of sources, to organize data, to interpret data, to test hypotheses and to formulate conclusions.

"Very little reliable evidence is available to indicate the extent to which the problem solving objective is provided for in day-to-day classroom activities. Still less evidence is available on the extent to which the objective is achieved with the young people who study science."²

What we do know, and what the Guide attempts to get at, is if students are to be efficient at problem solving, teachers must, first, be aware of and use scientific reasoning in their own classrooms. Secondly, they must provide their students with many opportunities to practice the skills inherent in problem solving. "If the teacher wishes to develop the ability to analyze problems, or interpret evidence, the skills must first be taught and then the teacher must provide classroom situations, day after day, when the pupil will have to use them. There is no easy way of teaching children to use the abilities of problem solving other than by setting classroom situations which call for their repetitive use."³

Problem solving is a significant part of a youngster's education and it cannot be left to chance. Just as the understanding of concepts will be incomplete, at best, if left to informal instruction, the problem solving abilities of students will remain haphazard and inefficient if not formally instructed. This aerospace guide provides the opportunity, not only to develop process skills and conceptual knowledge of aerospace, but also provides for the application of those skills and concepts to problem solving situations.

For a check-list of teacher problem solving practices, see "An Inventory of Problem-Solving Practices" in the Teacher Strategies section of the Introduction.

2. Sund, R., & Trowbridge, L. Teaching science by inquiry in the secondary school (2nd ed.). Columbus: Merrill, 1973. p. 569.

3. Sund, R., & Trowbridge, L. p. 570.

HELPING KIDS LEARN

In writing an aerospace guide, there ought to be a rationale for selection and inclusion of specific subject matter and method. Part of the rationale for selection of topics and strategies in this guide comes from what science and aerospace educators deem important to aerospace concept development. Another part comes from what we know about how children learn.

According to Piaget and other learning theorists, children have their own ways of examining their world and those ways can be described in somewhat defined stages. Teachers of junior high students, however, know that the range of abilities of students at the middle school levels covers a very wide span. Because the range may in fact reach from pre-primer to high school level, the authors have included information on the cognitive development of children from transition out of the Preoperational Stage, on their development in the Concrete Stage and on their development during the transition to the Formal Operations Stage. If the students in your classes are all primarily at level, you may wish to review Stage Three only.

Also, though in the past it has been generally accepted that children move to a level of abstract thinking at about the age of twelve, shortly before his death, Piaget proposed that the transition to formal operations may last until about the age of sixteen. This notion has been born out by data collected over the last decade.

Following is a detailed list of developmental behaviors taken from CHANGE STAGES 1 & 2 AND BACKGROUND (A UNIT FOR TEACHERS) published for the Schools Council by Macdonald Educational, London, England, 1973. It is included in the hope that teachers will be able to use the list to "spot" their own students' levels. Whether these students seem to be thinking on a higher or lower level, the list may aid the teacher in determining where these youngsters are developmentally and lessons can be modified to meet their needs. In addition, for those junior high students who may not be ready for some of the junior high materials, the teacher has the option of using the K - 6 materials of COME FLY WITH ME.

ON DEVELOPING AN INQUIRING MIND AND A SCIENTIFIC APPROACH TO PROBLEMS

STAGE 1 - Transition from Intuition to Concrete Operations Grades K, 1, 2

The characteristics of thought among children differ in important respects from those of children over the age of about seven years. The young child's thought has been described as "intuitive" by Piaget; it is closely associated with physical action and is dominated by immediate observation. Generally, young children are not able to think about or imagine the consequences of an action unless they have actually carried it out, nor are they yet likely to draw logical conclusions from their experiences. At this early stage the objectives are those concerned with active exploration of the immediate environment and the development of the ability to discuss and communicate effectively; they relate to the kind of activities that are appropriate to these young children, and which form an introduction to ways of exploring and ordering observations.

Attitudes, Interests and Aesthetic Awareness

1. Willingness to ask questions.
2. Willingness to handle both living and nonliving material.
3. Sensitivity to the need for giving proper care to living things.
4. Enjoyment in using all the senses for exploring and discriminating.
5. Willingness to collect material for observation or investigation.

Observing, Exploring and Ordering Observations

1. Appreciation of the variety of living things and materials in the environment.
2. Awareness of changes which take place as time passes.
3. Recognition of common shapes--square, circle, triangle.
4. Recognition of regularity in patterns.
5. Ability to group things consistently according to chosen or given criteria.

Developing Basic Concepts and Logical Thinking

1. Awareness of meaning of words which describe various types of quantity.
2. Appreciation that things which are different may have common features.

Posing Questions and Devising Experiments or Investigations

1. Ability to find answers to simple problems by investigation.
2. Ability to make comparisons in terms of one property or variable.

Acquiring Knowledge and Learning Skills

1. Ability to discriminate between different materials.
2. Awareness of the characteristics of living things.
3. Awareness of properties which materials can have.
4. Ability to use displayed reference material for identifying living and nonliving things.

Communicating

1. Ability to use new words appropriately.
2. Ability to record events in their sequences.
3. Ability to discuss and record impressions of living and nonliving things in the environment.
4. Ability to use representational symbols for recording information on charts or block graphs.

Appreciating Patterns and Relationships

1. Awareness of cause-effect relationships.

Interpreting Findings Critically

1. Awareness that the apparent size, shape and relationships of things depends on the position of the observer.

Concrete Operations. Early Stages. Grades 1, 2, 3

In this stage, children are developing the ability to manipulate things mentally. At first this ability is limited to objects and materials that can be manipulated concretely, and even then only in a restricted way. The objectives here are concerned with developing these mental operations through exploration of concrete objects and materials--that is to say, objects and materials which, as physical things, have meaning for the child. Since older children, and even adults prefer an introduction to new ideas and problems through concrete example and physical exploration, these objectives are suitable for all children, whatever their age, who are being introduced to certain science activities for the first time.

Attitudes, Interests and Aesthetic Awareness

1. Desire to find out things for oneself.
2. Willing participation in group work.
3. Willing compliance with safety regulations in handling tools and

- equipment.
4. Appreciation of the need to learn the meaning of new words and to use them correctly.
 5. Awareness that there are various ways of testing out ideas and making observations.
 6. Interest in comparing and classifying living or nonliving things.
 7. Enjoyment in comparing measurements with estimates.
 8. Awareness that there are various ways of expressing results and observations.
 9. Willingness to wait and to keep records in order to observe change in things.
 10. Enjoyment in exploring the variety of living things in the environment.
 11. Interest in discussing and comparing the aesthetic qualities of materials.

Observing, Exploring and Ordering Observations

1. Awareness of the structure and form of living things.
2. Awareness of change of living things and nonliving materials.
3. Recognition of the action of force.
4. Ability to group living and nonliving things by observable attributes.
 - a. ability to distinguish regularity in events and motion.

Developing Basic Concepts and Logical Thinking

1. Ability to predict the effect of certain changes through observation of similar changes.
2. Formation of the notions of the horizontal and vertical.
3. Development of concepts of conservation of length and substance.
4. Awareness of the meaning of speed and of its relation to distance covered.

Posing Questions and Devising Experiments or Investigations

1. Appreciation of the need for measurement.
2. Awareness that more than one variable may be involved in a particular change.

Acquiring Knowledge and Learning Skills

1. Familiarity with sources of sound.
2. Awareness of sources of heat, light and electricity.
3. Knowledge that change can be produced in common substances.
4. Appreciation that ability to move or cause movement requires energy.
5. Knowledge of differences in properties between and within common groups of materials.
6. Appreciation of man's use of other living things and their products.
7. Awareness that man's way of life has changed through the ages.

8. Skill in manipulating tools and materials.
9. Development of techniques for handling living things correctly.
10. Ability to use books for supplementing ideas or information.

Communicating

1. Ability to tabulate information and tables.
2. Familiarity with names of living things and nonliving materials.
3. Ability to record impressions by making models, painting and drawing.

Appreciating Patterns and Relationships

1. Development of a concept of environment.
2. Formation of a broad idea of variation in living things.
3. Awareness of seasonal changes in living things.
4. Awareness of differences in physical conditions between different parts of the Earth.

Interpreting Findings Critically

1. Appreciation that properties of materials influence their use.

Stage 2 - Concrete Operations. Later Stage. Grades 3, 4, 5

In this stage, a continuation of what Piaget calls the stage of Concrete Operations, the mental manipulations become more varied and powerful. The developing ability to handle variables--for example, in dealing with multiple classification--means that problems can be solved in more ordered and quantitative ways than was previously possible. The objectives begin to be more specific to the exploration of the scientific aspects of the environment rather than to general experience, as previously. These objectives are developments of those of Stage 1 and depend on them for a foundation. They are those thought of as being appropriate for all children who have progressed from Stage 1 and not merely for nine-to-eleven-year-olds.

Attitudes, Interests and Aesthetic Awareness

1. Willingness to cooperate with others in science activities.
2. Willingness to observe objectively.
3. Appreciation of the reasons for safety regulations.
4. Enjoyment in examining ambiguity in the use of words.
5. Interest in choosing suitable means of expressing results and observations.
6. Willingness to assume responsibility for the proper care of living things.

7. Willingness to examine critically the results of their own and other's work.
8. Preference for putting ideas to test before accepting or rejecting them.
9. Appreciation that approximate methods of comparison may be more appropriate than careful measurement.
10. Enjoyment in developing methods for solving problems or testing ideas.
11. Appreciation of the part that aesthetic qualities of materials play in determining their use.
12. Interest in the way discoveries were made in the past.

Observing, Exploring and Ordering Observations

1. Awareness of internal structure in living and nonliving things.
2. Ability to construct and use keys for identification.
3. Recognition of similar and congruent shapes.
4. Awareness of symmetry in shapes and structures.
5. Ability to classify living things and nonliving materials in different ways.
6. Ability to visualize objects from different angles and the shape of cross-sections.

Developing Basic Concepts and Logical Thinking

1. Appreciation of measurement as division into regular parts and repeated comparison with a unit.
2. Appreciation that comparisons can be made indirectly by use of an intermediary.
3. Development of concepts of conservation of weight, area and volume.
4. Appreciation of weight as a downward force.
5. Understanding of the speed, time, distance relation.

Posing Questions and Devising Experiments or Investigations

1. Ability to frame questions likely to be answered through investigations.
2. Ability to investigate variables and to discover effective ones.
3. Appreciation of the need to control variables and use controls in investigations.
4. Ability to choose and use either arbitrary or standard units of measurement as appropriate.
5. Ability to select a suitable degree of approximation and work to it.
6. Ability to use representational models for investigating problems or relationships.

Acquiring Knowledge and Learning Skills

1. Knowledge of conditions which promote changes in living things and nonliving materials.

2. Familiarity with a wide range of forces and of ways in which they can be changed.
3. Knowledge of sources and simple properties of common forms of energy.
4. Awareness of some discoveries and inventions by famous scientists.
5. Knowledge of ways to investigate and measure properties of living things and nonliving materials.
6. Knowledge of the origins of common materials.
7. Awareness of changes in the design of measuring instruments and tools during man's history.
8. Skill in devising and constructing simple apparatus.
9. Ability to select relevant information from books or other reference material.

Communicating

1. Ability to use non-representational symbols in plans, charts, etc.
2. Ability to interpret observations in terms of trends and rates of change.
3. Ability to use histograms and other simple graphical forms for communicating data.
4. Ability to construct models as a means of recording observations.

Appreciating Patterns and Relationships

1. Awareness of sequences of change in natural phenomena.
2. Awareness of structure-function relationship in parts of living things.
3. Appreciation of interdependence among living things.
4. Awareness of the impact of man's activities on other living things.
5. Awareness of the changes in the physical environment brought about by man's activity.
6. Appreciation of the relationships of parts and wholes.

Interpreting Findings Critically

1. Appreciation of adaptation to environment.
2. Appreciation of how the form and structure of materials relate to their function and properties.
3. Awareness that many factors need to be considered when choosing a material for a particular use.
4. Recognition of the role of chance in making measurements and experiments.

Stage 3 - Transition to Stage of Abstract Thinking Grades 5, 6, 7, 8, 9

This is the stage in which, for some children, the ability to think about abstractions is developing. When this development is complete their

thought patterns are capable of dealing with the possible and hypothetical, and are not tied to the concrete and to the here and now. It may take place between eleven and thirteen for some able children, for some children it may happen later, and for others it may never occur. The objectives of this stage are ones which involve development of ability to use hypothetical reasoning and to separate and combine variables in a systematic way. They are appropriate to those who have achieved most of the Stage 2 objectives and who now show signs of ability to manipulate, mentally, ideas and propositions.

Attitudes, Interest and Aesthetic Awareness

1. Acceptance of responsibility for their own and other's safety in experiments.
2. Preference for using words correctly.
3. Commitment to the idea of physical cause and effect.
4. Recognition of the need to standardize measurements.
5. Willingness to examine evidence critically.
6. Willingness to consider beforehand the usefulness of the results from a possible experiment.
7. Preference for choosing the most appropriate means of expressing results or observations.
8. Recognition of the need to acquire new skills.
9. Willingness to consider the role of science in everyday life.
10. Appreciation of the main principles in the care of living things.
11. Willingness to extend methods used in science activities to other fields of experience.

Observing, Exploring and Ordering Observations

1. Appreciation that classification criteria are arbitrary.
2. Ability to distinguish observations which are relevant to the solution of a problem from those which are not.
3. Ability to estimate the order of magnitude of physical quantities.

Developing Basic Concepts and Logical Thinking

1. Familiarity with relationships involving velocity, distance, time acceleration.
2. Ability to separate, exclude or combine variables in approaching problems.
3. Ability to formulate hypotheses not dependent upon direct observation.
4. Ability to extend reasoning beyond the actual to the possible.
5. Ability to distinguish a logically sound proof from others less sound.

Posing Questions and Devising Experiments or Investigations

1. Attempting to identify the essential steps in approaching a problem scientifically.
2. Ability to design experiments with effective controls for testing hypotheses.
3. Ability to visualize a hypothetical situation as a useful simplification of actual observations.
4. Ability to construct scale models for investigation and to appreciate implications of changing the scale.

Acquiring Knowledge and Learning Skills

1. Knowledge that chemical changes result from interaction.
2. Knowledge that energy can be stored and converted in various ways.
3. Awareness of the universal nature of gravity.
4. Knowledge of main constituents and variations in the composition of soil and of the earth.
5. Knowledge that properties of matter can be explained by reference to its particular nature.
6. Knowledge of certain properties of heat, light, sound, electrical, mechanical and chemical energy.
7. Knowledge of a wide range of living organisms.
8. Development of the concept of an internal environment.
9. Knowledge of the nature and variations in basic life processes.
10. Appreciation of levels of organization in living things.
11. Appreciation of the significance of the work and ideas of some famous scientists.
12. Ability to apply relevant knowledge without help of contextual cues.
13. Ability to use scientific equipment and instruments for extending the range of human senses.

Communicating

1. Ability to select the graphical form most appropriate to the information being recorded.
2. Ability to use three-dimensional models or graphs for recording results.
3. Ability to deduce information from graphs: gradient, area, intercept.
4. Ability to use analogies to explain scientific ideas and theories.

Appreciating Patterns and Relationships

1. Recognition that the ratio of volume to surface area is significant.
2. Appreciation of the scale of the universe.
3. Understanding of the nature and significance of changes in living and nonliving things.
4. Recognition that energy has many forms and is conserved when it is changed from one form to another.
5. Recognition of man's impact on living things--conservation, change,

- control.
6. Appreciation of the social implications of man's changing use of materials, historical and contemporary.
 7. Appreciation of the social implications of research in science.
 8. Appreciation of the role of science in the changing pattern of provision for human needs.

Interpreting Findings Critically

1. Ability to draw from observations, conclusions that are unbiased by preconception.
2. Willingness to accept factual evidence despite perceptual contradictions.
3. Awareness that the degree of accuracy of measurements has to be taken into account when results are interpreted.
4. Awareness that unstated assumptions can affect conclusions drawn from argument or experimental results.
5. Appreciation of the need to integrate findings into a simplifying generalization.
6. Willingness to check that conclusions are consistent with further evidence.

These States chosen here conform to modern ideas about children's learning. They conveniently describe for us the mental development of children between the ages of five and fifteen years, but it must be remembered that **ALTHOUGH CHILDREN GO THROUGH THESE STAGES IN THE SAME ORDER THEY DO NOT GO THROUGH THEM AT THE SAME RATES.**

SOME: children achieve the later Stages at an early age.

SOME: linger in the early Stages for quite a time.

SOME: never have the mental ability to develop to the later Stages.

ALL: appear to be ragged in their movement from one Stage to another.

These Stages, then, are not tied to chronological age, so in any one group of children there will be, almost certainly, some children at differing Stages of mental development.

TEACHING STRATEGIES

It is not enough that students are provided with activities or experiences in the classroom, no matter how engaging or educationally sound they may inherently be. Without the interaction between students and teachers who are prepared to listen, guide and help resolve discrepancies, there will be little learning at best and incorrect conceptualizing at worst.

The strategies used by the teacher are of utmost importance, then, to the student's acquisition of aerospace concepts. It is important to note that, though what a teacher knows about aerospace is important, what she or he knows about directing children's learning is equally important. Interaction with a teacher who assists students in thinking about what they have done, who helps them examine and evaluate the process under consideration and who shares the joy of discovery with them, will provide students with some of the most meaningful moments of their schooling.

Included in the following is a description of the three types of lessons to be found in the Guide, an outline of teacher verbal skills, a section on concept attainment strategies and a checklist of problem-solving practices teachers can use to help make the activities of this guide even more meaningful and useful for students.

TEACHING STYLES

Though there are many ways to present a lesson, most of the lessons in this guide will be presented in one of the following three teaching styles:⁴

EXPOSITORY

Definition: This model involves the presentation by the teacher of the facts, concepts, generalizations, theories, skills, etc., which students are expected to learn. In general, it involves the teacher as an intermediary between students and the scholars in the field of science who generate conclusions in some form. This model is quite often justified as

being most efficient in the teaching/learning time.

Purposes: To achieve content goals, to develop specific science related skills (metric system, use of equipment, graphing and other data collection skills, etc.) to gain knowledge of facts and explain phenomena.

Features: High teacher talk, large group instruction, little student interaction, frequent displays and exhibits or demonstrations.

Teaching Skills: Instructional procedures are characterized by such things as lecturing, recitation, use of audio-visual materials, students reading of textural materials and teacher demonstrations.

GUIDED DISCOVERY

Definition: This approach involves channeling student's activities so that they proceed through some or all the inquiry elements relating to a problem which a scientist has already completed. The basic idea is to lead students through inquiry, enabling students to generate independently, conclusions, concepts, generalizations, etc., similar to those of the scholar. In general, the intellectual problems to be inquired into and the elements of the inquiry are selected by the teacher, thus the term "guided" discovery.

Purpose: To achieve process goals, to gain working understanding (as opposed to verbal understanding) of concepts, principles and generalizations and to produce understandings and users of scientific procedures.

Features: Frequent discussion sessions, laboratory work, student to student interaction.

Teaching Skills: Instructional procedures are characterized by selection of appropriate problems, motivating students, structuring activities, building students' actions and leading large group and small group discussions.

OPEN DISCOVERY

Definition: This model involves the teacher as a facilitator who assists, rather than directs, student inquiry into intellectual problems which, in many cases, the students themselves have selected. The problems and inquiries may or may not have been taken up previously by scholars. Thus, the approach is much more open-ended and the results less predictable than in the guided inquiry approach. The students choose their own problem, their own inquiry strategies, and rather than teach the students elements of a predetermined inquiry strategy, the teacher encourages student experimentation and recognizes possible failure in the use of particular strategies.

Purpose: To provide opportunities to identify problems and for the application of understanding concepts and problem solving skills in the investigation of those real world or contrived problems.

Features: Discussions of real world problems, individual and small group work, laboratory and out of school work.

Teaching Skills: Instructional skills are similar to those in guided inquiry. They require, however, more flexibility and responsiveness to students than any of the teaching models. A type of creative improvisation on the part of the teacher is required.

A model of the three strategies may look like the following:

	Who determines the problem to be solved?	Who determines the process to be used to solve the problem?	Who actually solves the problem?
EXPOSITORY	Teacher	Teacher	Student
GUIDED DISCOVERY	Teacher	Student	Student
OPEN DISCOVERY	Student	Student	Student

4. Adapted from: Joyce, B., & Weill, M. Models of teaching (2nd ed.). Englewood Cliffs, N.J.: Prentice Hall, 1980.

TEACHER VERBAL SKILLS IN SCIENCE⁵

QUESTIONING SKILLS

If a goal of science is to further develop students' higher thought processes through discovery-inquiry techniques, the types of questions and problems students are presented with becomes a very important consideration. Recall and memory-type questions (lower-order questions) have a very definite place in all science areas but it is primarily the open-ended, divergent and probing questions (higher-order questions) which allow students the opportunity to use ideas rather than just remember them.

Higher-order questions are questions which require students to evaluate, infer, hypothesize, compare, apply a concept or principle, solve a problem, perceive cause and effect, project themselves into historical situations, and draw up new ideas.

Some Guide Lines for Effective Questioning:

- A. Try to use more open-ended, divergent questions in contrast to convergent closed questions.
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| 1. What did you observe? | vs | How far did your plane fly? |
| 2. Tell me about your kite. | | What shape is your kite? |
| 3. What happened in your experiment? | | Did you find out if you were right? |
| 4. What objects are in your system? | | Is the rudder in your system? |
- B. Try not to continually establish a T-C T-C T-C question and response pattern. It turns into an interrogation session not a discussion. The teacher is always forced to ask another question and the burden of thinking is on the teacher. Little child-child interaction will result. Questions which can be answered by a "yes" or "no" are directive and tend to limit possibilities for the children to express other ideas.
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| T - Did your rocket fly well? | |
| C - No. | |
| T - Did it fly? | |
| C - Yes. | |
| T - Did it fly far? | It would be better to say something like, "Tell me something about how your rocket worked after you changed it?" |
| C - No. | |
| T - How far did it fly? | |
| C - Not far. | |
- C. If you want to know something specific ask for an answer directly. Don't fish around and establish the mind-reading game. If you ask an open-ended question, accept the divergent responses you will get. Don't search for your preconceived answer.

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| T - What did you observe about the airport? | C - Some have propellers. |
| C - It has lots of planes. | T - I'm glad someone mentioned propellers. |
| T - Yes. | How many propellers are there on a plane? |
| C - Some are commercial and some are private planes. | C - 3. |
| T - Fine. | T - Really? |
| C - They make a lot of noise. | C - 4. |
| T - I see. | C - 2. |
| C - Some have double wings. | T - What do you think? |
| T - Anything else? | C - I wasn't looking at the propellers! |

- D. Be careful not to use too many fill-in-the-blank type questions. It promotes guessing for the right answer.

T - This part of the plane is aluminum and _____.

Avoid making statements and putting them in the form of a question.

T - The rockets all have the same essential shape, don't they?

RESPONSES (TO PUPIL COMMENT OR ANSWER) SKILLS

- A. Teachers need to develop a repertoire of responses to the comments and responses children make. Initially children need a great deal of praise and encouragement. No one response should be used for every occasion. As the teacher and children continue to work with the materials, the teacher should try to make more neutral or fewer responses to the children's comments in order to promote more interaction between the children.

Examples of responses:

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| I see. | Can you show us? |
| That's an interesting idea. | Silence |
| Thank you. | Do you agree with Jon's idea? |
| O.K. | How could we find out? |
| Repeat answer | That's a possibility. |
| Alright. | I don't agree. |
| What evidence do you have that... | |
| Fine. | |

- B. Any distinct pattern you may establish may be expected by a child and any deviation from that pattern may be misunderstood as a negative response.

T - Tell me about this object? (rocket)
 C - It's round.
 T - Good.

C - It's tall.
 T - Good.
 C - It has two engines on it.
 T - Good.
 C - It has two stages.
 T - It has two stages.
 C. Well, maybe it has three.

C. Be aware of the positive-negative type response you can make.

C - It will fly.
 T - Yes, but....

D. Be aware of responses made by children that may be a clue to the teacher that she has been giving too many or too much reinforcement or positive approval.

Child answers questions in question form. Example: C - It is going to crash?

Child looks at teacher for approving eye. (The teacher should try to focus her attention on the object itself, instead of the child's face.

WAIT SKILLS

A. Wait time after a teacher question--

If the students are being required to think more because of the use of higher order questions, the period of time that a teacher should wait for students to construct a response to a question should increase.

If, for example, more than one pattern can be imposed on a heap of objects, the student requires more time to process alternatives and decide which orderings are meaningful for him or her at that point in time.

Ask a question and follow it by silence. How long can you wait before you find it uncomfortable for you? Practice that skill.

Many children have learned to out-wait the teacher because sometimes teachers answer their own questions and do all the thinking for the children.

T - What shape is your object?
 C - No response
 T - It's kind of like a bird, isn't it?
 C - Yup.

B. Wait time before a teacher response--

Research shows that teachers tend to wait less than a second

after a question is asked by them or a response is given to their question before the teacher responds again. The period of time a teacher waits before replying to a student response should increase in order to promote higher level thinking on the student's part. Also, since the student may "open" with a variety of potentially acceptable responses, the teacher needs to hear what the student really said. If the teacher shifts the ground for discourse with his/her next response, then the student often learns to monitor the teacher rather than the system of objects.

MORE ON VERBAL SKILLS

In general you should hear yourself asking these types of questions:

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| "How well did we do this?" | "Where can we get information?" |
| "What is the problem" | "What would happen if....." |
| "How are they alike? Different?" | "Was our plan good?" |
| "What can we do to make it better?" | "Where can you find....." |
| "How could you make a....." | "Can you demonstrate....." |

If your children are using higher order thinking skills, you should hear these kinds of questions from them:

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| "If that's true, why....." | "How could that happen?" |
| "Where did you find that information?" | "How do you know that's true?" |
| "I understand that but, why...." | "Can we try that again?" |

5. Adapted from: Staley, F. A comparison study of the effects of pre-service teachers presenting one or two micro-teaching lessons to different sized groups of peers on selected teaching behaviors and attitudes in an elementary science methods course (Doctoral dissertation, Michigan State University, 1971). Dissertation Abstracts International, 1972, 2301-A. 43 - 7.

CONCEPT ATTAINMENT STRATEGIES⁶

Concepts are words or phrases that define certain classes of objects, events, situations, or systems. For example, one class or category of objects is TRIANGLE: closed figures that have three straight sides forming three angles are TRIANGLES. I have a concept of TRIANGLE if, whenever I come across a three-sided, closed figure whose sides are made up of straight lines (no matter what color), I mentally say, "TRIANGLE."

Conceptual understandings are rather nice things to have because concept understanding:

1. reduces the complexity of the environment (I can "store" all those various sizes and colors of three-sided, closed figures under TRIANGLE)
2. reduces the necessity of constant learning (If I run into a blue one, I'll still know it's a TRIANGLE).

When students understand a given concept, they are able to show us their understanding in various ways. If students have a concept of SPACECRAFT, students can:

A. Offer a lucid definition of the concept by listing (or identifying in some way) all the critical attributes that collectively define the concept (parroting back a textbook definition doesn't necessarily tell us anything!). For example, a student might say, "A spacecraft is a device that can have people in it or no people in it. What makes it a spacecraft is that it is made (1) to orbit the earth or (2) to fly outside the earth's atmosphere."

B. Identify an example of the concept and explain why this item is an example. For instance, a student might offer, "The Space Shuttle is a spacecraft because it (1) orbits the earth with a crew of two to six people. Even if it could orbit without people aboard it would still be a spacecraft because it orbits the earth."

C. Identify non-examples of the concept and explain why they are non-examples. Here a student might say, "A cruise missile is not a spacecraft. It can fly very far and very high but (1) it doesn't have enough energy to get into orbit or (2) the structural stability to withstand the lack of air pressure out of the atmosphere."

D. Identify those attributes that are critical to the concept from those that are true about the concept but are incidental to a definition of the concept. For example, a student might say, "The Space Shuttle is shaped like a rocket and it has wings which let it glide back to earth but that's not important to deciding whether it's a spacecraft or not."

6. Adapted from: Porter, L., et al. The skills infusion laboratory handbook for inservice facilitators. Berkley, MI: Skills Diffusion Laboratory, Berkley Schools, 1981. pp C18-21.

LEARNING CONCEPTS WITHOUT INSTRUCTION

In order for a child to arrive at an understanding of a concept, it is essential that s/he work through certain steps; for example, in developing a concept of airplane the child:

1. experiences an example of the concept and is cognizant of the attributes of this particular example (jet airplane and its attributes)
2. hears the concept label (the word) for this example ("airplane")
3. experiences other, somewhat dissimilar, examples (propeller, float, glider, etc.) of the concept and is cognizant of their attributes
4. hears the same concept label applied to these examples (airplane)
5. "sorts out" the critical attributes from the incidental ones in order to discern those that are essential to a definition of the concept (throws out "wheels," "fuel tank," "engine," while keeping "wing," "stabilizer," "fuselage," and such.)
6. organizes the language necessary to communicate a lucid definition (if language ability allows) of the concept. The definition ought to include the critical attributes of the concept.

LEARNING CONCEPTS IN SCHOOL

It is clear that some concepts are learned, or, at least, partly learned, through random experience ("family," for example). Formal schooling, then, provides instruction designed to broaden, to make more complete, the students' understanding of the concept until it is a rich, full understanding.

Other concepts are generally introduced in a formal educational setting (triangle, square, goods and services, economic interdependence, technology). It is formal education that build students' understandings of these kinds of concepts and one of the most effective and most efficient strategies for teaching to an understanding of a specific concept is Hilda Taba's CONCEPT ATTAINMENT strategy.

Taba's strategy is an instructional strategy that reflects the naturally occurring mental processes theorized to account for how we build conceptual understandings. It is a strategy designed to teach specific concepts; it is a strategy that provides students with an opportunity to "discover" the critical attributes of the concept, to "discover" the concept's meaning.

Essentially, Taba's CONCEPT ATTAINMENT strategy has eight steps:

1. The first step requires the teacher to provide the concept label,

indicating that the lesson's objective is to learn the concept's definition. "At the end of this lesson you will be able to tell me what a spacecraft is. You'll be able to define it and/or give me examples of spacecraft and you will have discovered for yourselves the meaning of spacecraft; I won't have to give you a dictionary definition because you'll be able to give me yours."

2. The second step requires the teacher to provide examples of the concept and for each example . . .
3. Ask focused questions concerning each of the examples. For example, "What does this craft do?" "How far from the earth's atmosphere can this craft fly?" Ask similar questions about each example in order for students to note what is the same about all the examples of spacecraft that you present.
4. Provide non-examples of the concept and for each non-example . . .
5. Ask the same focused questions in order for students to note how the non-examples are different from the examples.
6. Check for understanding by requesting that students provide additional examples of the concept.
7. Check for understanding by requesting that students list the critical attribute(s) of the concept.
8. Provide opportunities for students to use their new learning in a variety of ways in order to retain their understanding of the concept.

BUT FIRST . . . Before a teacher can utilize the concept attainment strategy, s/he needs to have identified the CRITICAL ATTRIBUTES OF THE CONCEPT about to be taught. It is not always easy, but it is essential that the teacher have firmly in mind a lucid definition of the concept, the critical attributes of the concept that form the definition, and mental images of examples of the concept.

Teachers can use the concept attainment strategy at those points in a unit where some common word meanings are necessary for a clear understanding (a meaningful understanding) of the objects, behaviors, events, or situations that are being studied. For example, if students are involved in a study of aerospace, there are some basic terms that must be understood before real, meaningful comprehension of the unit can take place - "action/reaction," "micro-gravity," "exploration," "interpreting data," come to mind. Quick verbal definitions from the teacher, written textbook or dictionary definitions WILL NOT insure meaningful understanding of concepts such as these. No one can guarantee that the concept attainment strategy will result in perfect understanding either, but the probability that students will develop real understanding of concepts is considerably increased.

AN INVENTORY OF PROBLEM-SOLVING PRACTICES⁷

An inventory of problem-solving practices can be used by a teacher in making an appraisal of the extent to which he or she provides for the suggested item under the various elements in problem solving. By making a self-analysis of practices in regard to this objective, teachers should be able to locate their strengths and weaknesses. This would provide a reliable basis for improving classroom practice.

Inventory of Problem-Solving Practices

Directions: Check your response to each of the following items in the proper space at the right.

A. SENSING AND DEFINING PROBLEMS:

To what extent do you:

1. help pupils sense situations involving personal and social problems?
2. help pupils recognize specific problems in these situations?
3. help pupils in isolating the single major idea of a problem?
4. help pupils state problems as definite and concise questions?
5. help pupils pick out and define the key words as a means of getting a better understanding of the problem?
6. help pupils evaluate problems in terms of personal and social needs?
7. help pupils to be aware of the exact meaning of word-groups and shades of meaning of words in problems involving the expression of ideas?
8. present overview lessons to raise significant problems?
9. permit pupils to discuss possible problems for study?
10. encourage personal interviews about problems of individual interest?

Often	Occasion- ally	Seldom	Never

7. Sund, R., & Trowbridge, L. Teaching science by inquiry in the secondary school (2nd ed.). Columbus: Merrill, 1973.

[illegible]

1. provide a wide variety of sources of information?
2. help pupils develop skill in using reference sources?
3. help pupils develop skill in note taking?
4. help pupils develop skill in using aids in books?
5. help pupils evaluate information pertinent to the problem?
6. provide laboratory demonstrations for collecting evidence on a problem?
7. help pupils to develop skill in interviewing to secure evidence on a problem?
8. provide controlled experiments for collecting evidence on a problem?
9. provide for using the resources of the community in securing evidence on a problem?
10. provide for using visual aids in securing evidence on a problem?
11. evaluate the pupils' ability for collecting evidence on a problem as carefully as you evaluate their knowledge of facts?

To what extent do you:

1. help pupils develop skill in arranging data?
2. help pupils develop skill in making graphs of data?
3. help pupils make use of deductive reasoning in areas best suited?
4. provide opportunities for pupils to make summaries of data?
5. help pupils distinguish relevant from irrelevant data?
6. provide opportunity for pupils to make outlines of data?
7. evaluate the pupil's ability to organize evidence as carefully as you evaluate their knowledge of facts?

[illegible]

1. help pupils select the important ideas related to the problem?
2. help pupils identify the different relationships which may exist between the important ideas?
3. help pupils see the consistencies and weaknesses in data?
4. help pupils state relationships as generalizations which may serve as hypotheses?
5. evaluate the pupils' ability for interpreting evidence as carefully as you evaluate their knowledge of fact?

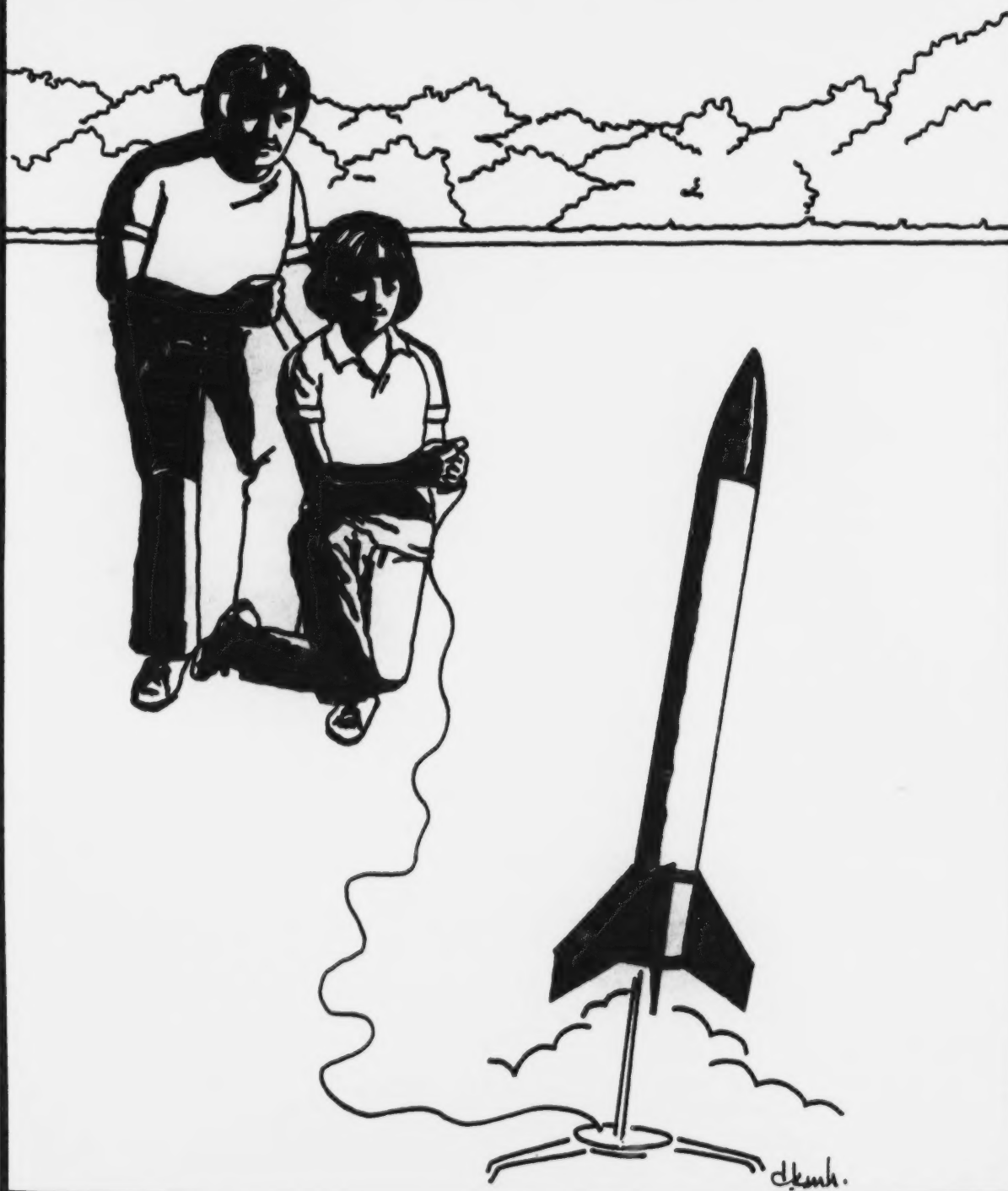
To what extent do you:

1. help pupils judge the significance or pertinence of data?
2. help pupils check hypotheses with recognized authorities?
3. help pupils make inferences from facts and observations?
4. help pupils devise controlled experiments suitable for testing hypotheses?
5. help pupils recognize and formulate assumptions basic to a given hypothesis?
6. help pupils recheck data for possible errors in interpretation?
7. evaluate the pupils' ability for selecting and testing hypotheses as carefully as you evaluate their knowledge of facts?

To what extent do you:

1. help pupils formulate conclusions on the basis of tested evidence?
2. help pupils evaluate their conclusions in the light of the assumptions they set up for the problem?
3. help pupils apply their conclusions to new situations?
4. evaluate pupils' ability to formulate conclusions as carefully as you evaluate their knowledge of facts?

PHYSICAL SCIENCE



CONTENTS

"It's just a matter of imagination how far we go with rockets. You haven't seen anything yet."

Robert Goddard,
1945

PHYSICAL SCIENCE OBJECTIVES

1. TO GAIN A WORKING KNOWLEDGE OF THE PRINCIPLES OF FLIGHT
2. TO UNDERSTAND THAT FLIGHT IS POSSIBLE ONLY WITHIN THE BOUNDS OF CERTAIN SCIENTIFIC PRINCIPLES.
3. TO UNDERSTAND THE FORCES THAT ACT ON AN AIRCRAFT.
4. TO UNDERSTAND THE BASIC PRINCIPLES OF PROPULSION SYSTEMS.
5. TO DEVELOP SUFFICIENT KNOWLEDGE OF AIRCRAFT STRUCTURE, FUNCTION, CONTROL AND PROPULSION TO BE ABLE TO BUILD AND TO FLY A MODEL AIRPLANE AND OR ROCKET.

LESSONS

- | | |
|---|--|
| 1. WHY AN AIRPLANE FLIES | 13. RECOVERING SPACECRAFT WITH PARACHUTES. |
| 2. AIRPLANE CONTROL SURFACES | 14. RECOVERING SPACECRAFT WITH PARAGLIDERS |
| 3. WIND TUNNEL | 15. WIRING A LAUNCH SYSTEM |
| 4. PROPELLER THRUST DEMONSTRATION | 16. MODEL ROCKET CONTEST |
| 5. FLIGHT INSTRUMENTS | 17. BE COOL |
| 6. BUILDING A MODEL AIRPLANE | 18. SATELLITES IN ORBIT |
| 7. ELECTRICAL CIRCUITRY/AIRCRAFT LIGHTS | 19. OVAL ORBITS |
| 8. AIRPORT FIELD TRIP | 20. INERTIA AND GRAVITY - CIRCULAR ORBITS |
| 9. BUILDING A MODEL ROCKET | 21. "G" WIZZ |
| 10. ROCKET NOZZELS | 22. NAVIGATING IN SPACE |
| 11. EASY AS 1 - 2 - 3 | 23. ROVE, ROVE, ROVE, THE MOON |
| 12. CONSTRUCTING A "THRUSTOMETER" | |

WHY AN AIRPLANE FLIES



Objectives: To review the concepts of Lift, Thrust, Drag, and Gravity in relationship to flight; to review and demonstrate Bernoulli's Principle.

Materials: Paper; pencils; study sheet.

Teacher Background Information: Many ways are available to demonstrate Bernoulli's principle simply in the classroom. Several ways are given here. Additional information on flight is available in the K - 6 edition of Come Fly With Me!.

Procedure: (A.) 1. Have the students tape a piece of paper to the side of a pencil. 2. Hold the pencil sideways in two hands and, 3. Blow gently across the top of the paper. 4. Observe the action of the paper.

(B.) 1. Place the edge of a piece of paper between the pages of a book. 2. Hold the book at an angle and, 3. blow gently across the edge of the book with the paper in it. 4. Observe the paper.

(C.) 1. Attach the hose of a vacuum cleaner to the "blow" connection. 2. Hold the hose straight up and turn the vacuum on. 3. Place a ping pong ball in the stream of air blowing out of the hose. 4. Observe the action of the ball.

Note: In all cases the paper should rise and the ball should "fly" in the stream of air. The movement of air over the curved surface of the paper (airfoil) creates a low pressure area above the "wing" and allows the higher pressure air below the paper to "lift" it. Bernoulli's principle states that a fluid-like air exerts less pressure when it is moving quickly than when it is moving slowly. (Actually, an increase in the velocity of a fluid is always accompanied by a decrease in the pressure exerted by that fluid.) The lift created by the movement of air over a wing must be enough to support the weight of a plane and its contents for the plane to fly.

Another force acting against a plane is drag. Drag is created by the resistance of the air to the movement of a plane through the air and the mass of the plane. Usually, the sleeker the design, the less drag is created. The action used to counteract drag is forward motion. This motion is created by the "thrust" of a motor or engine in a powered plane or by gravity in a glider.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large Group

TIME:
45 minutes

TYPE OF ACTIVITY:
Student Activity and
Demonstration

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Lift
Thrust
Drag
Bernoulli's principle

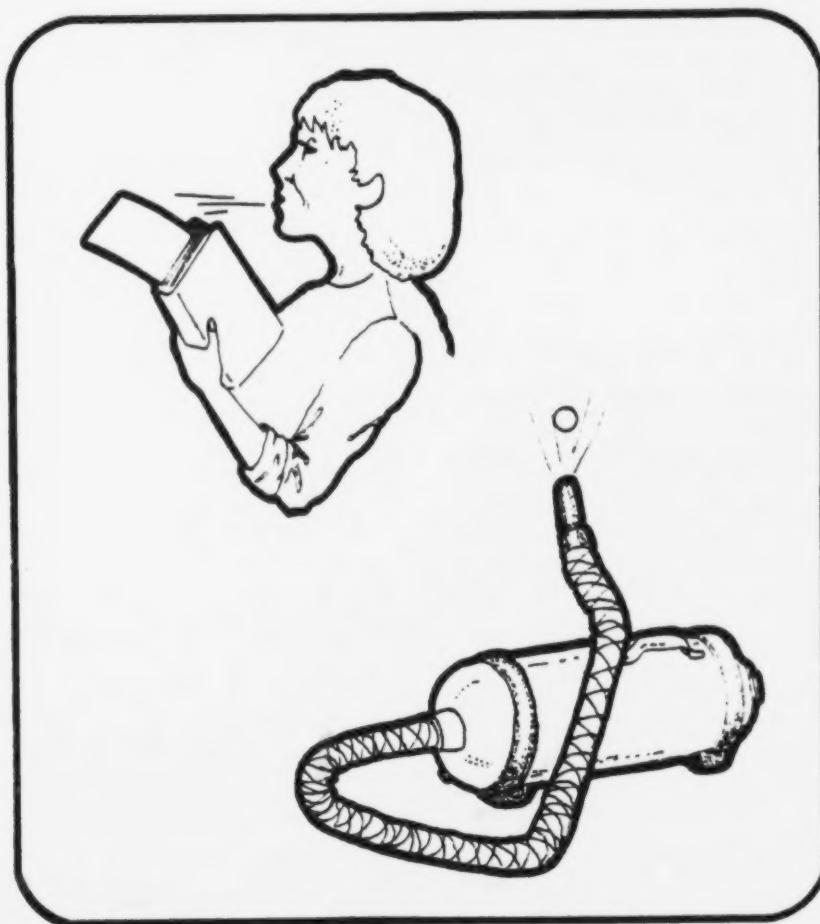
SKILLS:
Observation
Inference
Modeling

RESOURCES:
BK - F.
FM - 10,11,12,14

1. Have the students review the diagram on the next page.

2. Have them identify how each of the forces affecting flight are present in their plane.

Extensions: Have the students research Bernoulli and learn more about the experiments he did which led to the description of the principle bearing his name. Have the students consider how Bernoulli's principle works in a rocket with no wings. Have the students explore ways to increase lift in a wing. Explore the effects of different shapes in wings on lift.



Thrust may be produced by engine-driven propellers, jets or rockets.

THRUST is a force created by a power source which gives an airplane forward motion.

The weight of the airplane is produced by the attraction of gravity.

LIFT is an upward force that acts against gravity because of a partial vacuum created above the surface of an airplane's wing causing the wing to be "lifted" upward.

Lift is produced by (a) the difference in the speed of air flowing over the wing surfaces and (b) the angle of attack.

DRAG is the resistance the air offers because of friction which slows the forward movement of an airplane through the air. It is a backward force that works against thrust.

Drag may be reduced by streamlining the shape of the plane.

GRAVITY is a force which pulls downward on the plane.

— THE FORCES INVOLVED IN FLYING A PLANE —

AIRPLANE CONTROL SURFACES



Objectives: To learn the names of the control surfaces of an airplane; to discover the effects of the manipulation of control surfaces on the flight characteristics of an airplane; to review the four forces of flight and relate the manipulation of the control surfaces to the four forces.

Materials: Three 20cm x 20cm pieces of light cardboard cut into airplane shapes (use the pattern provided); two pieces of soda straw about 7cm long; 1 pencil with an eraser or a cork; 1 straight pin; tape.

Procedure: 1. Cut out three airplane shapes from the cardboard using the pattern provided.

2. Save scrap pieces and cut out three tail pieces also shown in the pattern.

3. Cut the solid lines indicated for plane 1 which will produce ailerons. Fold on the dotted lines. Tape or glue a soda straw piece on the bottom of the airplane as shown in the diagram. Attach one of the tail pieces.

4. Assemble plane 2 as shown, cutting the lines which produce elevators. Attach the second piece of straw on the bottom of the plane's wing crossing the center of balance. Attach a tail piece.

5. Assemble plane 3 producing a tail which has a moveable rudder as shown. Attach this plane to the eraser of the pencil or to a cork as in the diagram.

6. Place a knitting needle or piece of wire through the straws of the first two planes and gently blow or hold them in front of a fan. Bend one aileron up and one down. Have the students observe the resulting action on the plane. Reverse the aileron positions and observe again. With the second plane, raise or lower the elevator and observe the action. With the third plane, move the rudder left or right and hold in front of the air source again. Review with the students that the ailerons act on the axis of ROLL, the elevators act on the axis of PITCH and the rudder acts on the axis of YAW.

Teacher Note: It is important that the students understand that the rudder on a plane in flight does not turn a plane

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

2-45 Minute
periods

TYPE OF ACTIVITY:

Student Investigation
and Teacher Discussion

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Roll
Pitch
Yaw
Control Surface

SKILLS:

Modeling
Manipulation of
Variables

RESOURCES:

BK - F
FM - 10,11,12,14

like the rudder of a boat. In a plane the rudder acts on the axis of yaw. Turning is accomplished by banking the plane with the ailerons and the action of the rudder combined. The rudder does keep the plane straight or can be used to offset side forces from the wind in order to maintain a particular path over the ground. It should become apparent to the students that the control surfaces are used to put the plane into a particular attitude relative to the ground (straight and level). This attitude then allows the pilot to cause the plane to climb or descend, to turn right or left, to correct a flight path over the ground, or to do a combination of any of these things.

Extensions: You may wish to show the films listed below to see how inventors have attempted to devise creative ways of controlling the flight of airplanes.

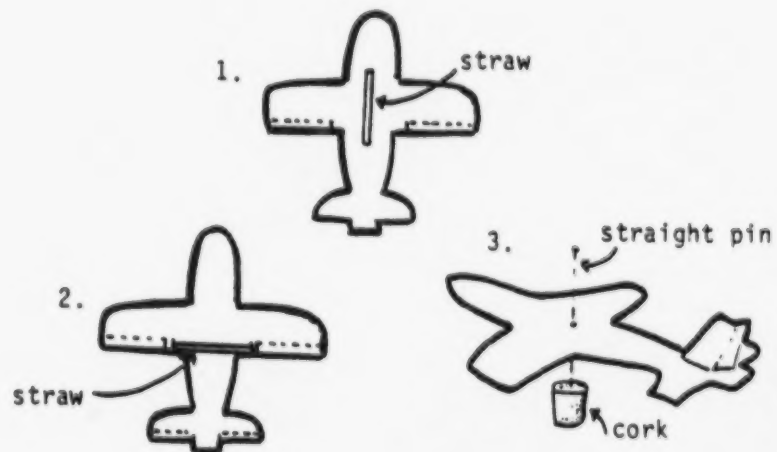
AIRCRAFT ODDITIES

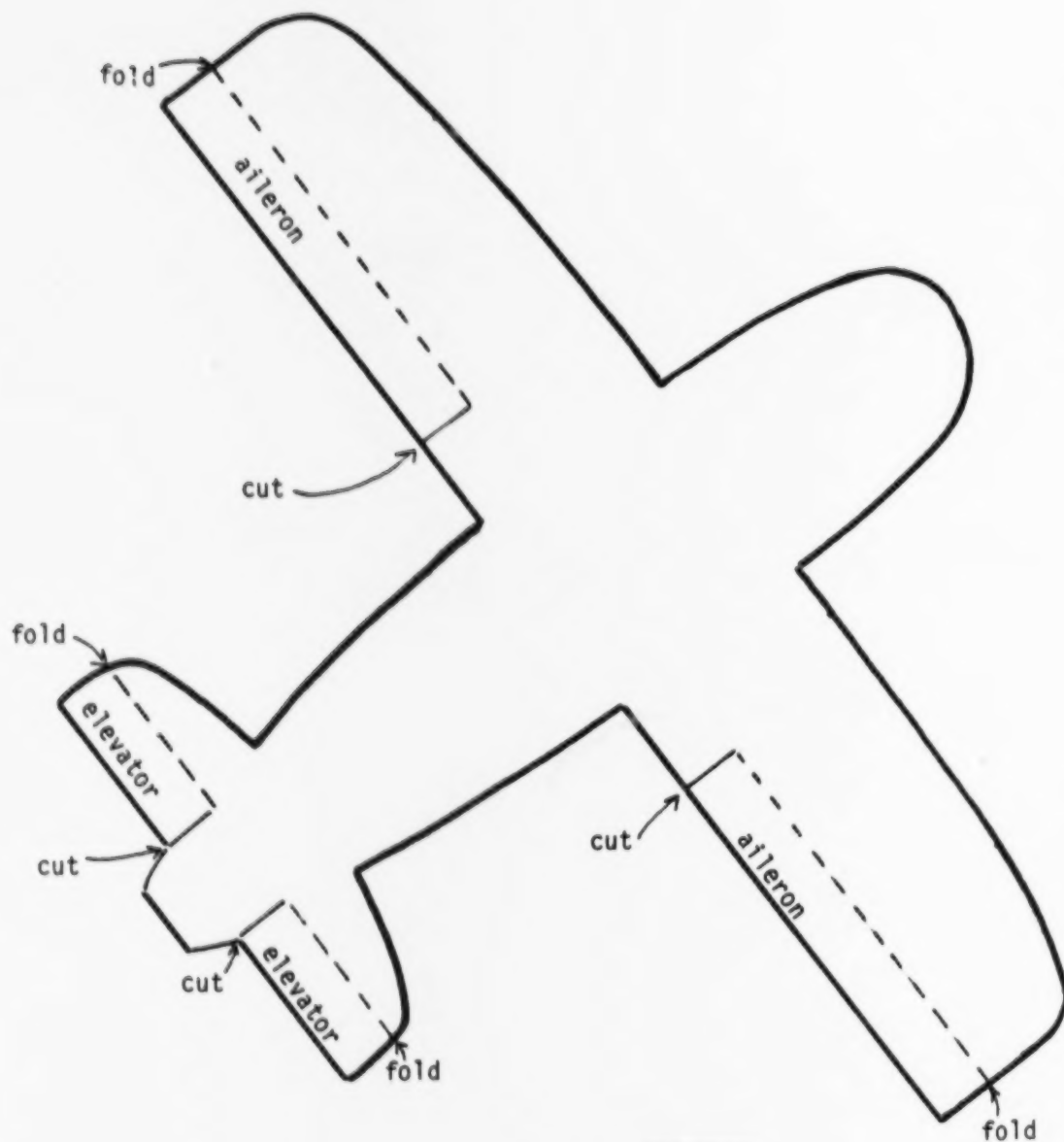
A compilation of old newsreel stories showing early attempts at aircraft design. Black & White - 12 min.

FLYING MACHINES

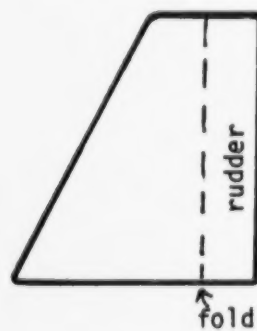
Discusses aircraft of the future and reviews some of the exotic aircraft of today. Narrated by Cliff Robertson. Color - 27½ min.

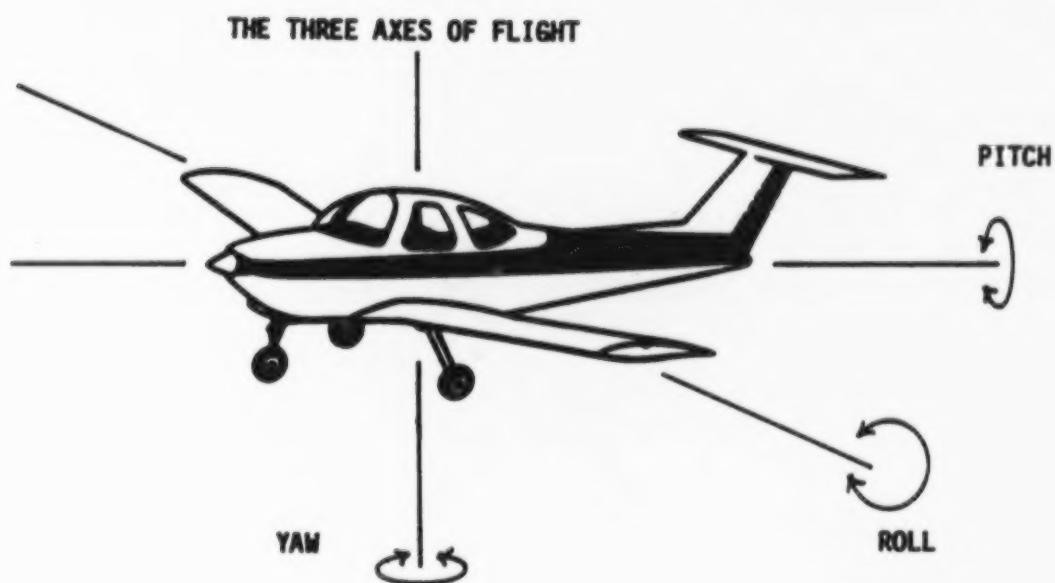
Both films are available from NASA





AIRPLANE CONTROL SURFACES PATTERN





WIND TUNNEL

3

Objectives: To demonstrate the effects of the manipulation of flight control surfaces of a plane on its flight characteristics; to demonstrate on a small scale how scientists test those characteristics on larger planes and rockets before they fly; to realize some of the benefits which may occur from scientific "modeling".

Materials: Piece of furnace pipe or carpet roll about 1.3 meters long; piece of transparency film for the tunnel window; separations from an egg carton (available at the grocery, some bakeries, a restaurant, or you may build a similar one from strips of light cardboard); heavy cardboard or a box the same size as the egg carton divider; book tape or duct tape; an electric fan; 2 small hooks of the type used to hang cups; metal shears or a saber saw depending on the material your tunnel is to be constructed of.

Teacher Background Information: The tunnel-like chambers through which air is passed at different velocities are used to study airflow over an object like a plane or rocket. The automobile industry also uses wind tunnels in their research to produce more fuel efficient cars. Some of the wind tunnels in the United States are large enough to hold full size planes or rockets for testing. One such tunnel is at the Langley, NASA Research facility in Virginia. A supersonic tunnel is at the NASA Lewis Research Center in Cleveland, Ohio. A model of the shuttle was tested and perfected in this tunnel before it was produced.

There are any number of small wind tunnels which you or a small group of students can prepare. The one suggested here is a relatively simple one requiring a minimum of exotic materials. If you would like to prepare a more sophisticated model, refer to additional sources such as science teacher resource manuals.

Procedure: Open the carton separators and strengthen the corners with tape. Open a box at both ends and place the separator grid into the box. They should fit snugly. Cut a window near one end of the roll or pipe and cover it with the clear film or acetate. Tape the film down using the book binder's tape. Fasten the hooks on opposite sides of the tube so that a plane hanging from the top one will be positioned in front of the window. (Refer to the

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

2 or 3-60 minute periods

TYPE OF ACTIVITY:

Construction and Student Investigation

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Scale Model
Control Surface

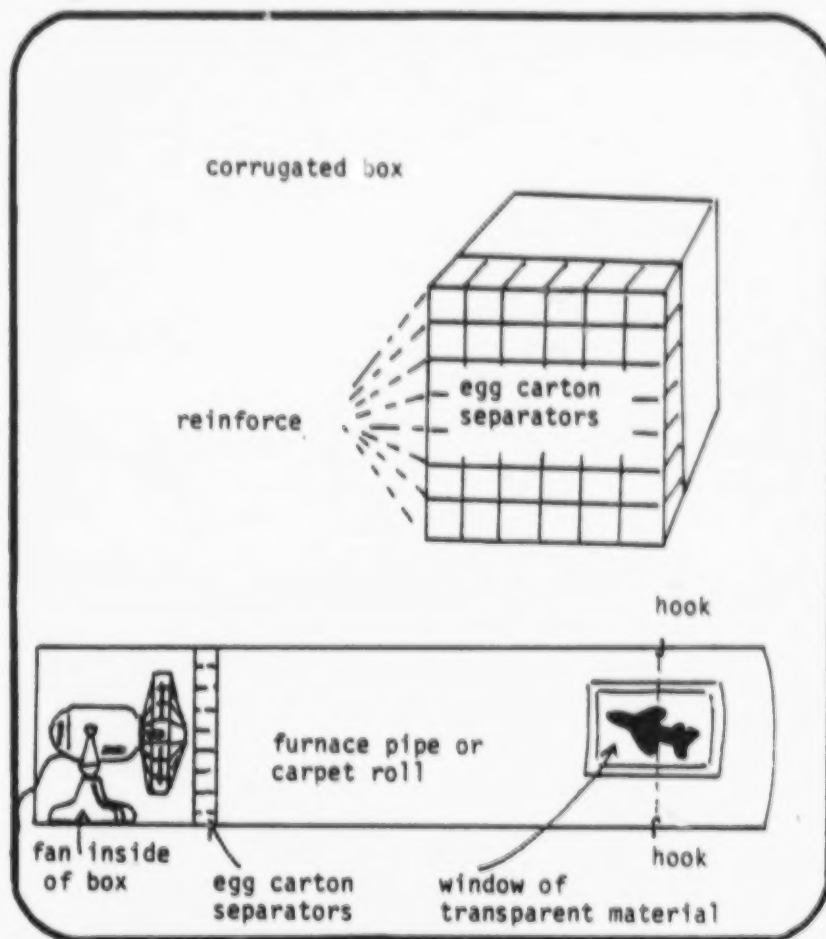
SKILLS:

Modeling
Experimenting
Interpreting Data

RESOURCES:

BK - F

illustration). Set the egg carton separations flush against the pipe or tube and place a fan in the box holding the separators. The separators will straighten the swirling air from the fan.



from DEMONSTRATION AIDS
for AVIATION EDUCATION,
Civil Air Patrol, FAA
reprint GA-20-30

1. Have the students prepare a suspension system for the models to be tested.

a. Use a strong rubber band of the type you find on model airplanes. Cut the band in one place.

b. String two note book paper reinforcement rings on the rubber band and glue them together.

c. Tie the cut ends of the rubber band back together again.

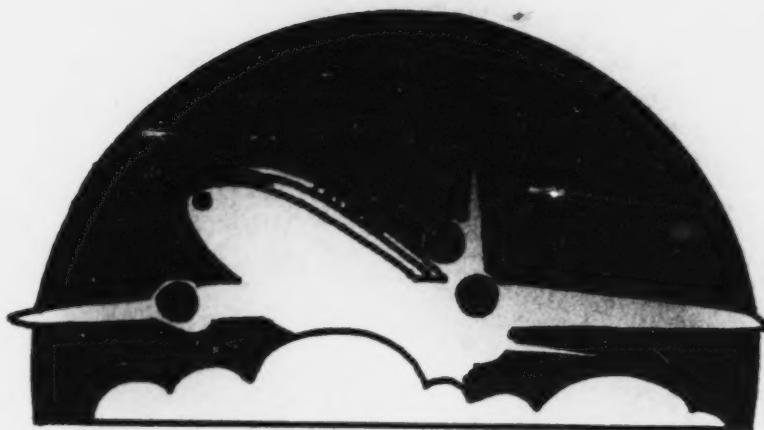
d. To attach the model to be tested, place a pin through the model and the ring near the center of gravity of the model.

e. Attach a similar rubber band to the lower hook as well.

2. Have the students start by building paper airplane models and testing the effects of manipulation of the control surfaces of the model. They should discover that to climb, elevators are up; to dive, elevators are down; to turn right, the rudder is right, the right aileron is up, the left aileron is down; to turn left, the rudder is left, the left aileron is up, the right aileron is down.

3. Have the students investigate the effects of changing the center of gravity on the stability of the plane.

Extensions: Have the students prepare and test model rockets, before actual flight, in the tunnel and compare the actual flight results with their data collected from the tests after launch. Have them find out more about wind tunnel testing of automobiles and investigate spin offs from the science of aerodynamics to the auto industry.



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

45 minutes

TYPE OF ACTIVITY:

Teacher Demonstration
Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Propeller Pitch
Newton's 3rd Law
Thrust

SKILLS:

Observation
Inference
Hypothesizing

RESOURCES:

BK - F,I
FM - 10,14,15

Objectives: To investigate how a propeller produces thrust and the results of that thrust; to relate the results of this investigation to Newton's Third Law of Motion.

Materials: 6 or more round pencils or pieces of doweling; a flat board; an electric fan and extension cord; model airplane propellers.

SAFETY NOTE: DO NOT ALLOW THE STUDENTS TO INVESTIGATE THE PITCH OF THE PROPELLER WHILE THE FAN IS PLUGGED IN!

Procedure: 1. Have the students examine the propellers and the blades of the fan. Have them hypothesize as to the direction of thrust based on the direction of rotation.

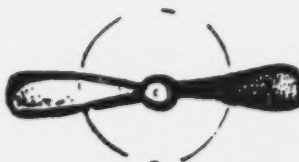
2. Have them rotate the blades slowly to see what action they may have on the air.

3. Place the board on several pencils which have been placed parallel to one another on a hard flat surface. Place the fan on the board and plug it in.

4. Have the students observe the resulting action/reaction and feel the thrust of air from the propeller in the fan.

5. Have them then apply this information to their hypotheses and explain which direction thrust will be produced by the model airplane propellers.

Extension: Have the students actually make a propeller out of wood. Have them investigate the effect of pitch (angle of attack) of different propellers. Relate this experiment to the one on rocket nozzels which dealt with velocity as a result of pressure. Relate the propeller concept to a boomerang.



FLIGHT INSTRUMENTS

Objectives: To introduce the basic flight instruments contained in an airplane; to manipulate models of flight instruments and learn how to read them.

Materials: Activity sheets; copies of the demonstration sheets for each student or group of students; tag board; scissors; rubber cement; brass fasteners.

Teacher Background Information: This lesson deals with the instruments used in beginning flight training. At first glance, the instruments look difficult to use but, in fact, with a minimum of practice they are quite simple.

The lesson, though it takes time to prepare, is well worth the effort as a model for reading data from instruments and as an example of the importance of precision when reading instruments.

Early navigation in planes meant following landmarks on the ground by day and by night, following a trail of bonfires set by farmers. Later, light beacons spaced a few miles apart, were the state-of-the-art for night flying in good weather. Sometimes pilots were forced to land in a farmer's field along the way if weather turned bad and the farmer would find passengers from the airline as uninvited guests for the night. By the late 1920's and early '30's, a system of emergency airports had also been established along cross continent routes. Modern systems of navigation use radio beacons which are read by instruments in the plane and point the way along a flight path.

The AIRSPEED INDICATOR is read like the speedometer of a car and tells the pilot how fast the plane is moving through the air. The speed of a head wind would be subtracted from the airspeed reading to arrive at the speed over the ground (ground speed). Tail winds should be added to the airspeed. Colored arcs on each plane's airspeed indicator tell the pilot what the safe operating speeds are and when flaps or landing gear can be extended.

The ALTIMETER tells the pilot how high above sea level the plane is which can be interpreted as how high above the ground the plane is by looking at a map and finding the altitude of the ground below. There are 3 hands on the altimeter. The shortest indicates 10,000 feet, the middle length indicates 1,000 feet and the longest hand indicates 100 foot increments.

The TURN AND SLIP INDICATOR tells the pilot when he or she is making a coordinated turn. The needle indicates how the ailerons are being used and the ball indicates

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Individual or
Small group

TIME:
2-45 Minute periods

TYPE OF ACTIVITY:
Simulation
Student Investigation

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Flight Instruments
Visual Flight Rules
Instrument Flight
Rules

SKILLS:
Construction
Observation
Interpreting Data

RESOURCES:
BK - F,I
FM - 10,12,13



whether the rudder is being used correctly to balance the turn. The ball stays in the center when a turn is balanced, otherwise the ball "slips" to the side.

The ARTIFICIAL HORIZON indicates at what angle the plane is climbing, descending or banking. This instrument is essential when a pilot can not see outside.

The VERTICAL SPEED INDICATOR tells the pilot how fast the plane is climbing or descending in feet per minute.

The COMPASS indicates magnetic heading.

Several other instruments are included in the handouts. Have the students do a little research to find out how they work and what they are used for.

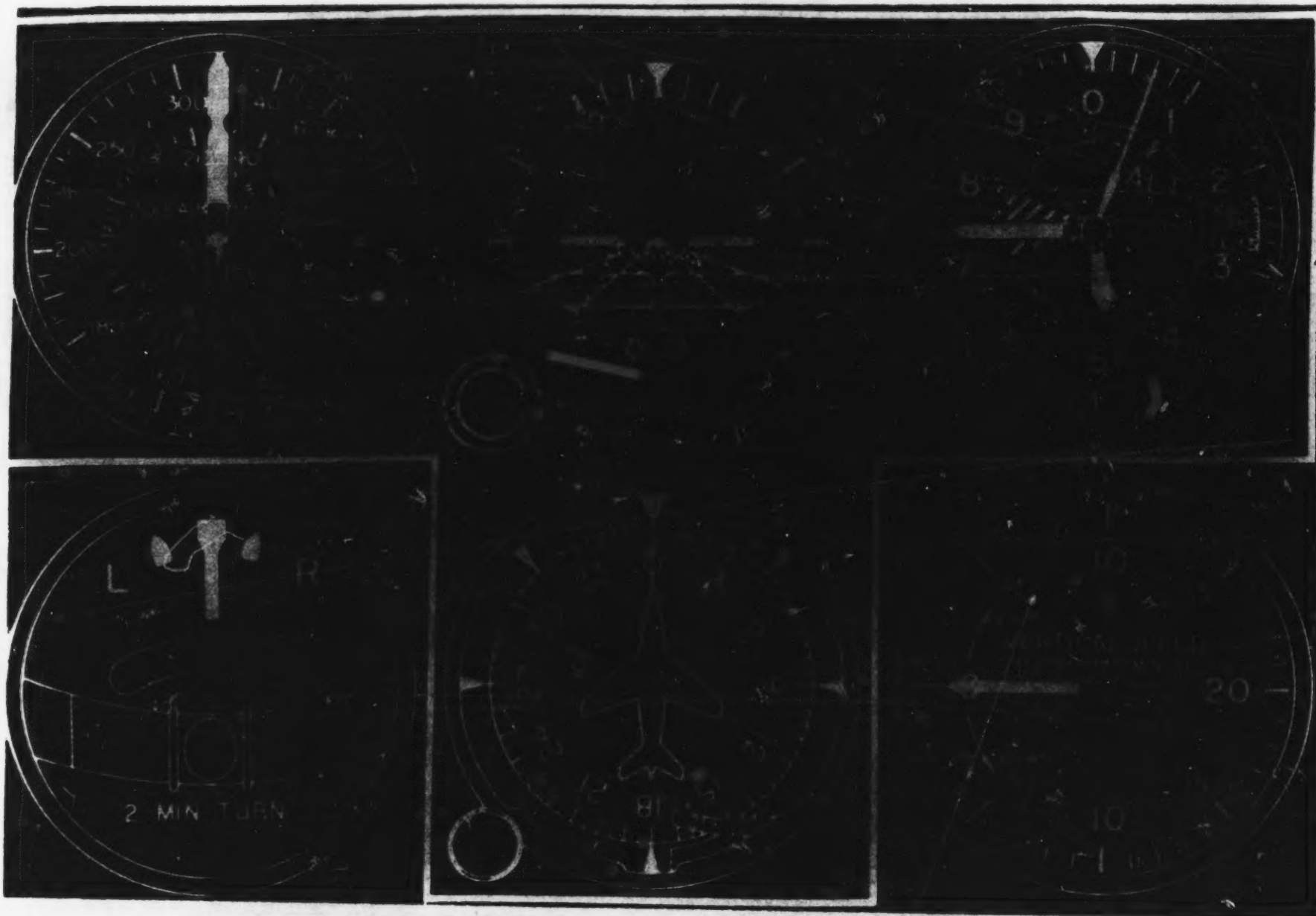
Procedure: 1. Have the students carefully cut out the instrument faces from the sheets.

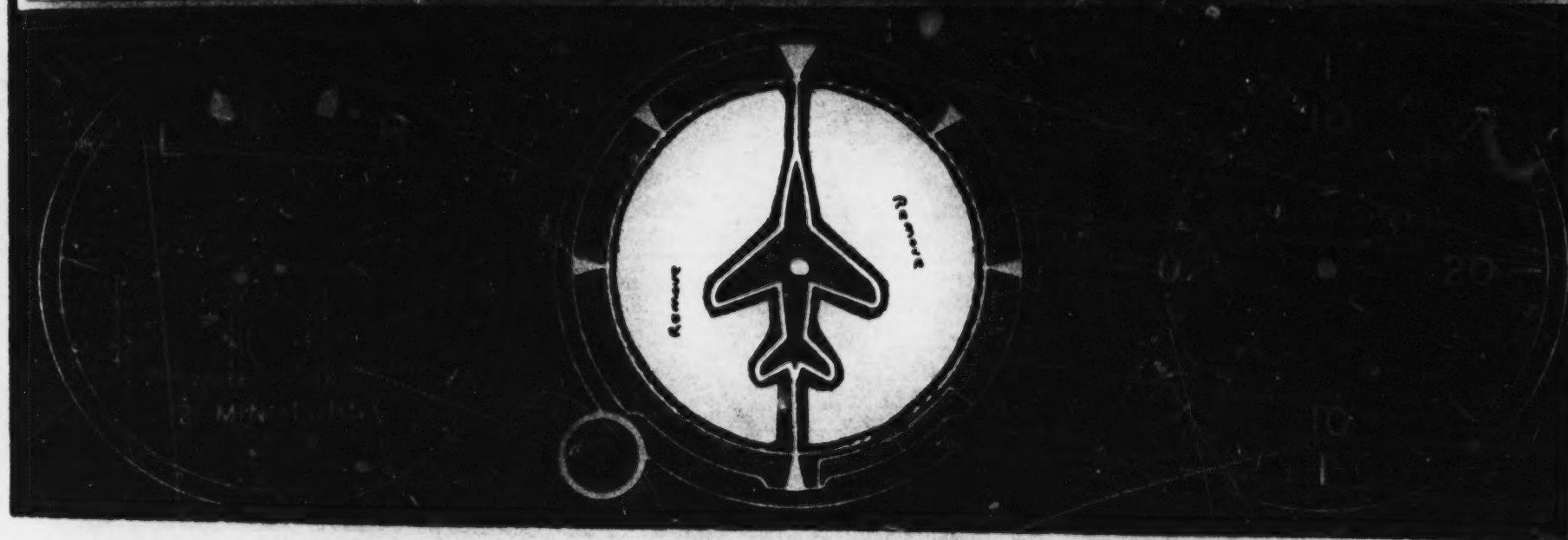
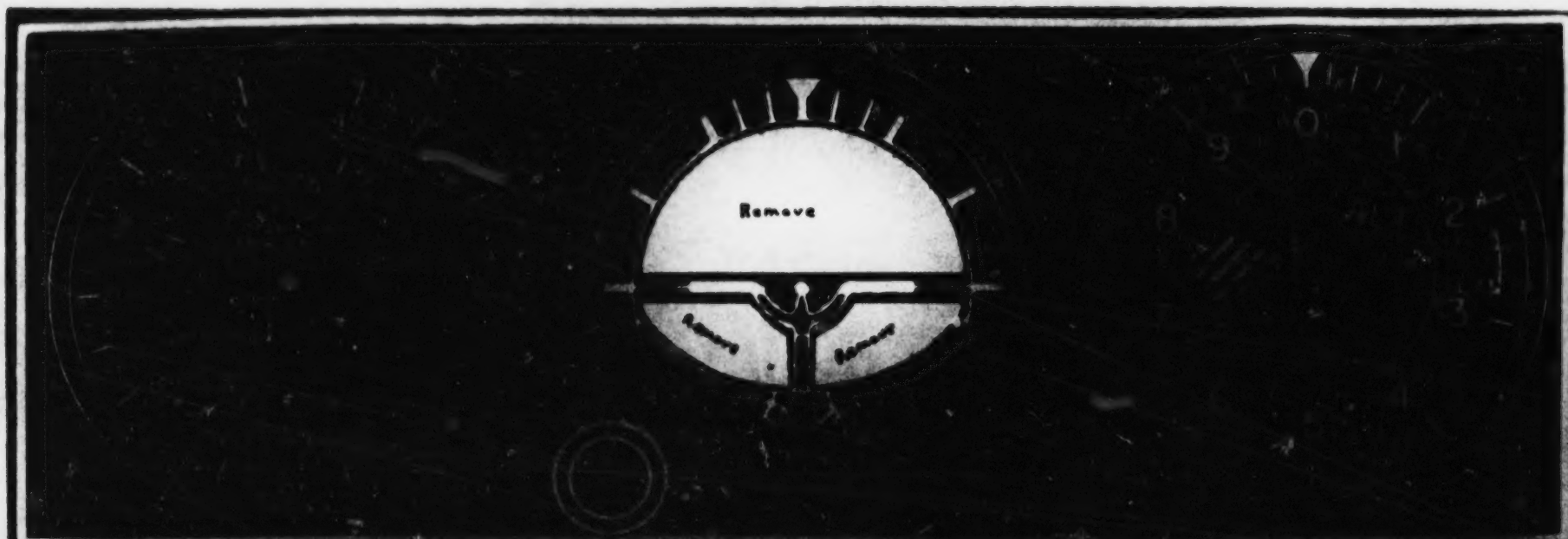
2. Glue the faces on tagboard.
3. Cut out the hands or dials which move and ..
4. Attach them to the instrument faces with brass fasteners.
5. Review with the students how to read the instruments using the activity sheets.
6. Have the students set the dials on the instruments they made to read at the same values as the instruments on the activity sheet.
7. Show the students some examples of different settings on a demonstration instrument and ask them to interpret what the setting or the reading means.
8. Prepare a list of possible instrument readings and have the students set their instruments to match the readings. Have the students check each other.
9. Have them identify which instruments are needed for flying VFR (on visual flight rules).
10. Have them identify the additional instruments needed for IFR flying (instrument flight rules) in bad weather or through clouds.

Extensions: Have the students prepare a mock-up of a plane's control panel complete with radios. Have them research and add to the panel, instruments which are found on more expensive planes, then, explain their function to the class. Take a trip to a local airport and see the actual instruments in a plane. Have a pilot or air traffic controller come to the class and talk about the instruments and flying. Arrange for a flight to see the instruments and controls in use. (See activity # 8).

Instrument illustrations,
pp 47-52, courtesy Cessna
Aircraft Corp.

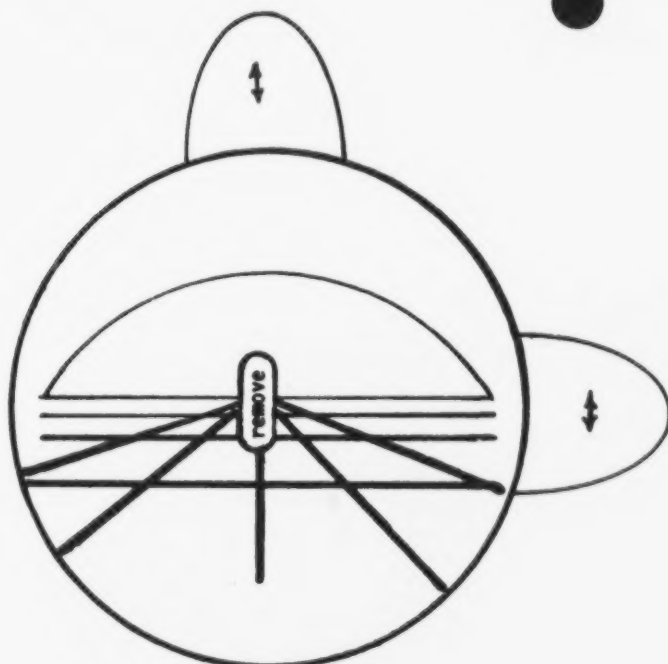
Instrument Activity
Sheets, pp 53-58,
courtesy Beech Aircraft







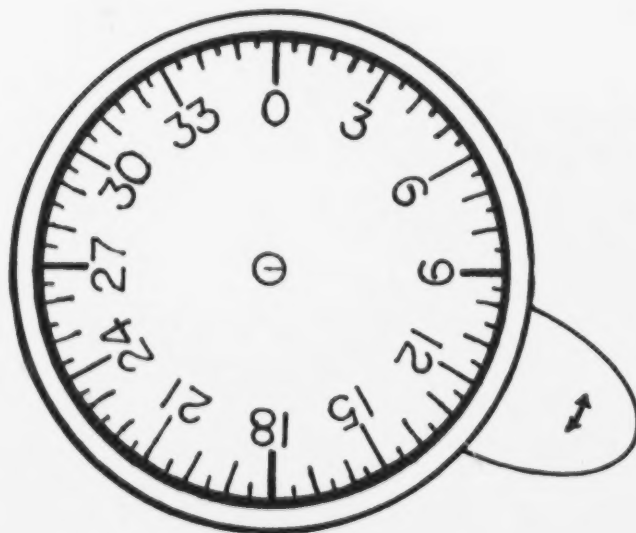
AIRSPPEED



ARTIFICIAL HORIZON



TURN AND BANK



GYRO COMPASS



1000



10,000



100

ALTIMETER



VERTICAL
SPEED

Copy onto tag board.

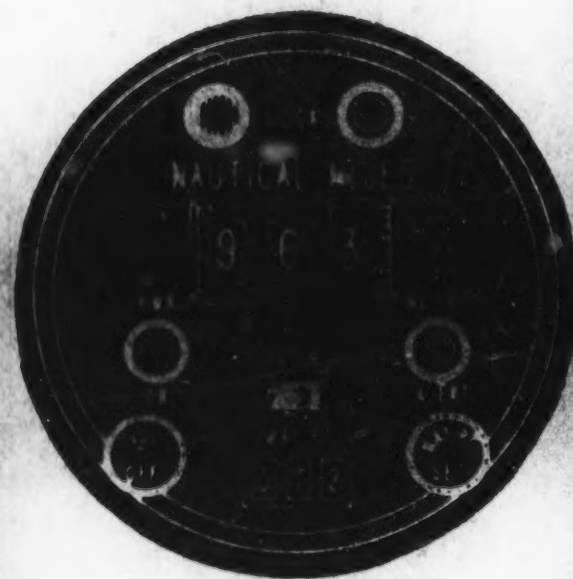
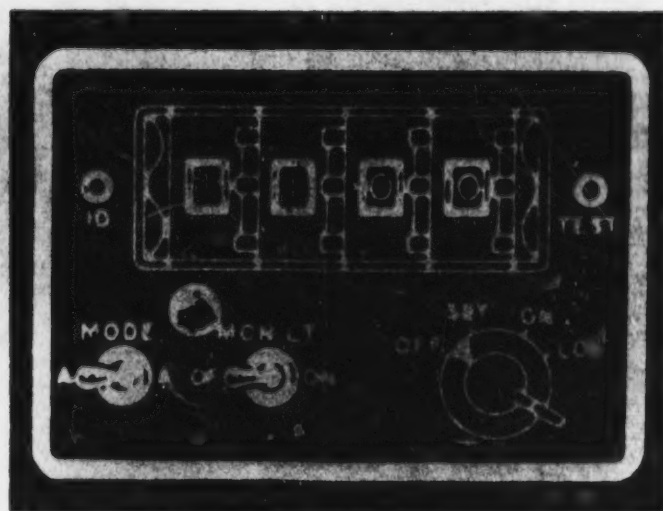
Cut out each dial carefully.

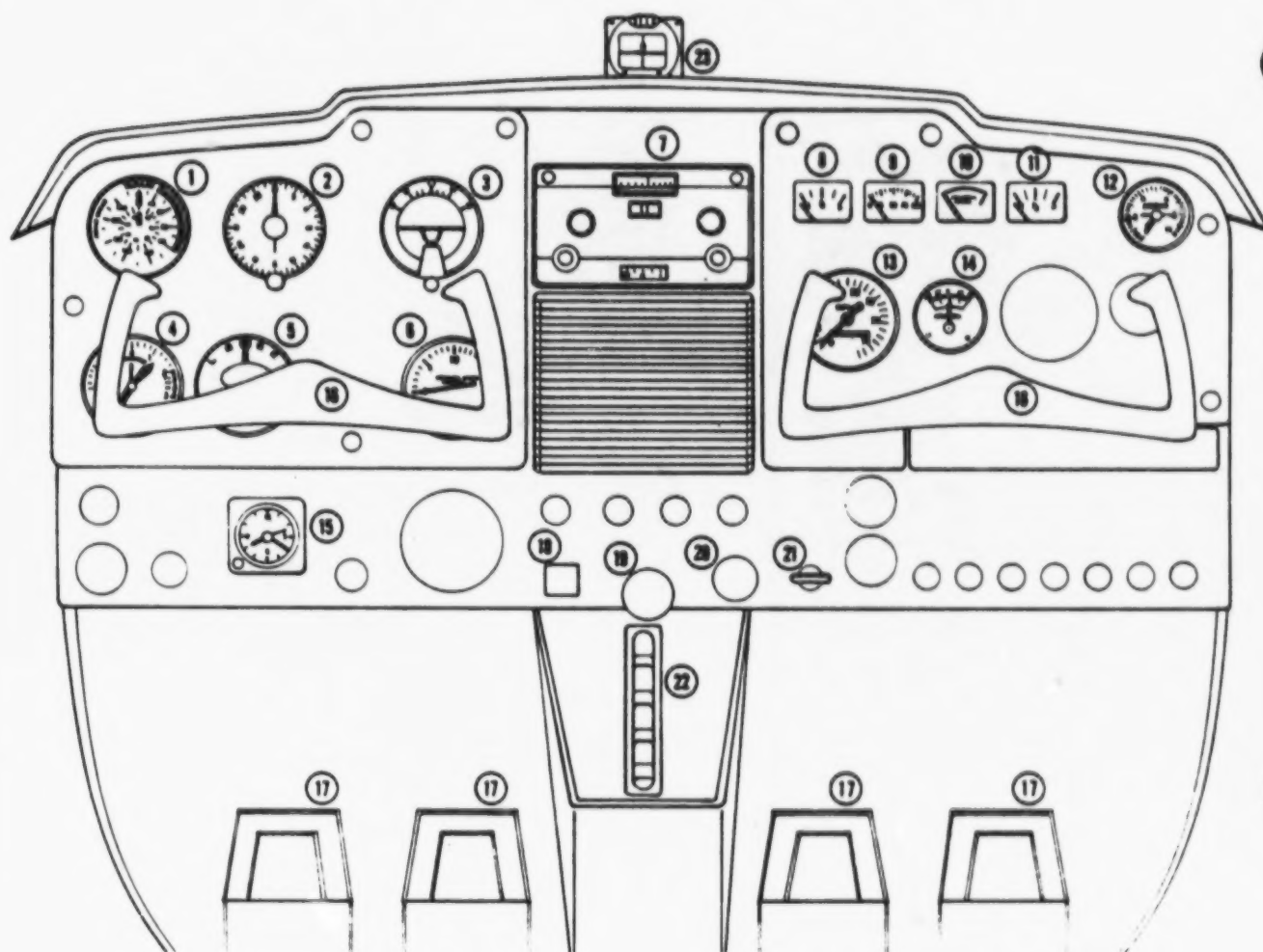
Punch out the hole.

Place "hands" on top of
the proper instrument.

Place the horizon & the
Compass Rose behind the
proper instrument face.

Fasten each to the instrument
with a brass fastener.





Instrument Panel

- | | |
|--|---|
| 1. Airspeed indicator | 13. Tachometer (measures revolutions per minute of propeller) |
| 2. Gyroscopic compass | 14. Battery — generator indicator |
| 3. Artificial horizon | 15. Clock |
| 4. Altimeter | 16. Control wheel (dual) |
| 5. Turn-and-bank indicator | 17. Rudder pedals |
| 6. Vertical speed (rate-of-climb—descent) indicator | 18. Carburetor heat control |
| 7. VHF navigation — communication radio | 19. Throttle control |
| 8. Fuel gauge (left tank) | 20. Fuel-air mixture control |
| 9. Oil pressure gauge | 21. Wing flaps control |
| 10. Oil temperature gauge | 22. Trim tab control |
| 11. Fuel gauge (right tank) | 23. Magnetic compass |
| 12. Suction indicator (run by vacuum pump, which activates gyroscopic instruments) | |

INSTRUMENT ANSWER SHEET

ARTIFICIAL HORIZON



PITCH LEVEL, MEDIUM
RIGHT BANK



PITCH LEVEL, SHALLOW
LEFT BANK



PITCH NOSE UP, WINGS
LEVEL



PITCH NOSE DOWN,
SHALLOW LEFT BANK

THE COMPASS

- A. 36° B. 276°
C. 306° D. 216°
E. 354° F. 126°

ALTIMETER

- A. 1,280 B. 7,889

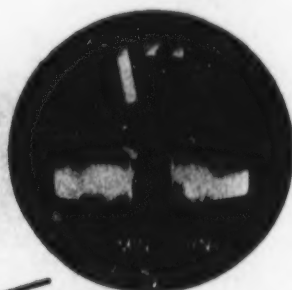
AIRSPPEED INDICATOR

- A. 151 B. 85

VERTICAL SPEED INDICATOR

- A. Level B. Descending

TURN AND SLIP



Standard Rate Co-
ordinated Turn to the
Left

Standard Rate Turn to
Right, Slipping to the
Outside

Steep Turn to the Left,
Slipping to the Inside



THE COMPASS

The magnetic compass as used in airplanes is a simple self contained instrument. A "compass card" is mounted on a floating ring which has two magnetized needles, which always point to magnetic north. The compass card has letters for cardinal headings, that is, N (north), E (east), S (south) and W (west). Each 30° interval of direction is represented by a number from which the last zero is omitted. Between the numbers, the card is graduated for each 5°. For example, on the compass 240° would look like 24.

What is the compass reading on each of the examples shown below:



A. _____



B. _____



C. _____



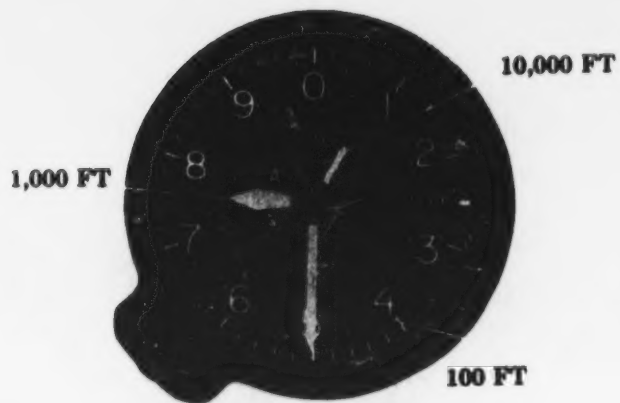
D. _____



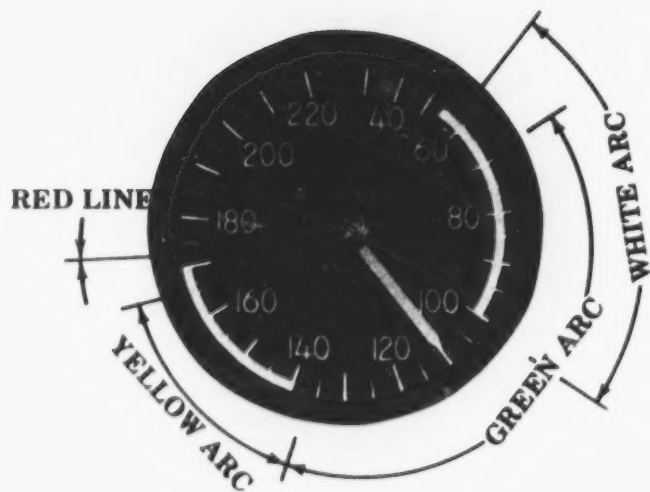
E. _____



F. _____



INDICATED ALTITUDE
IS 7,500 FT



INSTRUMENTS

The **ALTIMETER** tells the pilot how high the airplane is above sea level.

What is the indicated altitude on the two altimeters shown below.



A. _____



B. _____

The **AIRSPPEED INDICATOR** is similar to a speedometer in a car. It shows the speed the airplane is traveling through the air.

What is the indicated airspeed shown on the two examples:



A. _____

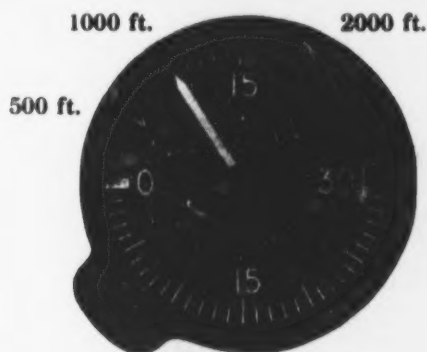


B. _____



TURN AND SLIP INDICATOR

The TURN and SLIP INDICATOR shows the rate and direction of a turn. It tells the pilot if he is performing a coordinated turn using all his controls most efficiently.



VERTICAL SPEED INDICATOR

The VERTICAL SPEED INDICATOR shows the RATE of climb or descent in feet per minute.

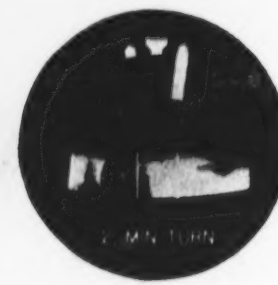
INSTRUMENTS



Standard Rate Co-ordinated Turn to the Left



Standard Rate Turn to Right, Slipping to the Outside



Steep Turn to the Left, Slipping to the Inside

Draw connecting lines from the turn and bank indicator to the correct description.



A. _____



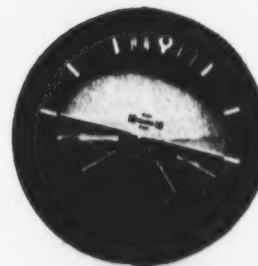
B. _____

According to the Vertical Speed Indicators shown above in each case is the airplane climbing, descending or in level flight.

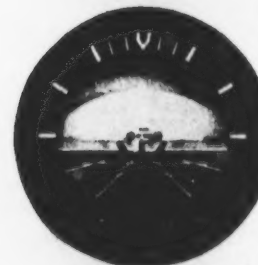


The ATTITUDE INDICATOR shows the aircraft's position in relation to the earth's horizon. The white semi-circle of the instrument represents the sky. The white dot represents the nose of the airplane in relation to the horizon and the bars represent the wings. In straight and level flight the nose and wings correspond to the horizon line. (See example above.) Although this instrument is used at all times, it is particularly important at night and when flying in clouds in order to control the position of the airplane relative to the earth.

INSTRUMENTS



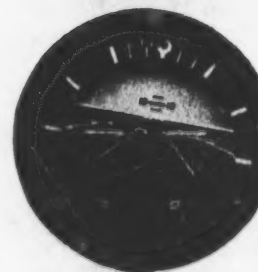
**PITCH LEVEL, MEDIUM
RIGHT BANK**



**PITCH LEVEL, SHALLOW
LEFT BANK**



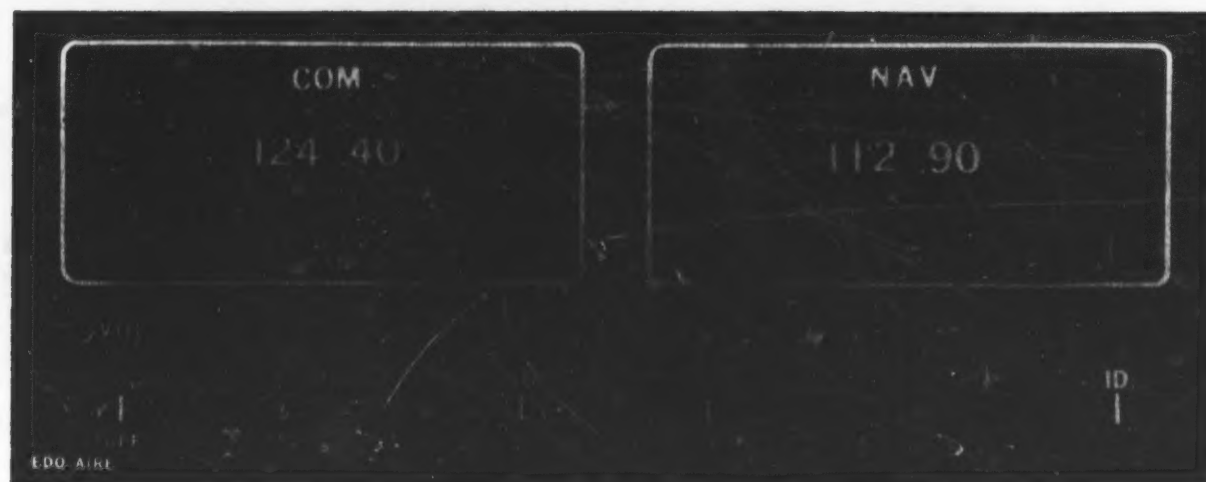
**PITCH NOSE UP, WINGS
LEVEL**



**PITCH NOSE DOWN,
SHALLOW LEFT BANK**

Draw connecting lines from the horizon display to the proper description.

INSTRUMENTS



NAV/COM RADIO

The radio shown above serves two purposes:

- 1) The COM [communications transceiver (transmitter and receiver)] is for two-way communication with the ground.
- 2) The NAV (navigation receiver) is used to receive the signals from the VOR station (See Compass Page 4D) is selected by the pilot in advance to assist him in staying on a direct course to the VOR station by use of the VOR INDICATOR (pictured below at right). This enables the pilot to navigate on the "HIGHWAYS IN THE SKY".



VOR INDICATOR

Pilot should fly a heading of 35° to the station.

BUILDING A MODEL AIRPLANE

Objectives: To review the parts of an airplane; to produce, test, and fly a model airplane; to review the effect of forces which influence flight.

Materials: Model airplane kits or balsa sheets and sticks (as called for in the model for which plans are provided at the back of this lesson.) **NOTE:** A number of very inexpensive kits are available. The Delta Dart, available from Midwest Products Co., 400 S. Indiana St., Hobart, IN 46342, is a good beginners plane and costs less than 50 cents per copy when purchased in lots of 40.

Procedure: 1. Have the students assemble their planes according to the directions.

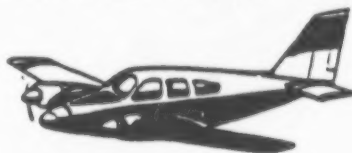
2. Test fly the planes and balance them to achieve the most stable flight characteristics.

3. Have the students try to identify the possible causes of any problems with the flight of their plane. What forces might be out of balance? What control surfaces on a plane might counteract the problem? Where is the center of balance in the plane?

4. If the students are not familiar with the control surfaces and their effect on flight, review each of the axes of flight and the parts of the plane which control those axes. (See the study sheet in lesson # 2)

5. If the students still cannot identify the cause of the problem, refer to the trouble shooting sheet.

Extensions: Have a flying contest with the planes. Give points for the longest flight; the highest; the furthest; the most acrobatic; the best design; best built. Have the class work together to build a more complex model, perhaps one with an engine. Have a local enthusiast bring a radio controlled plane or a control line model and fly it for the class. Take a field trip to a local airport and have a pilot show the students the control surfaces and the airplane controls which move them on a full size plane.



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual or Small

TIME:

Several 45 minute periods

TYPE OF ACTIVITY:

Construction and Testing of models

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Forces of Flight
Stability

SKILLS:

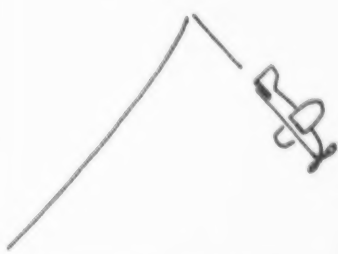
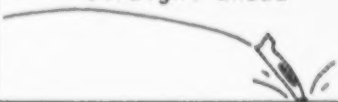
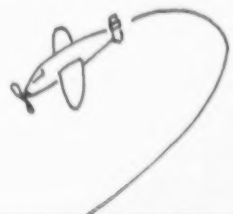
Construction
Modeling
Manipulation and Control of Variables

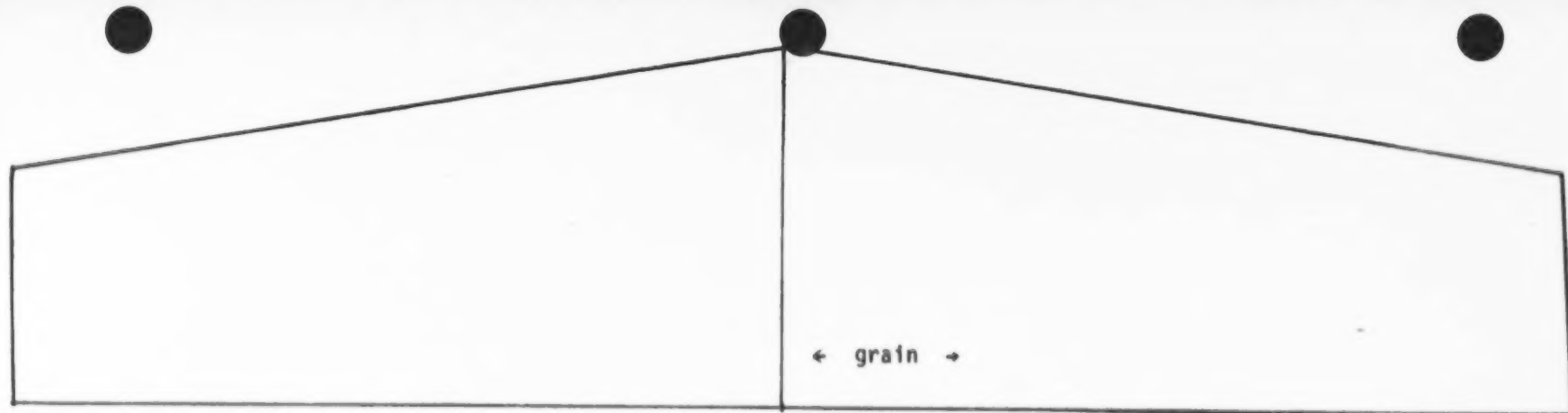
RESOURCES:

BK - F,I
FM - 13,14,22

TROUBLE SHOOTING CHART FOR MODEL PLANES

The following assumes a reasonably well built model and calm air.

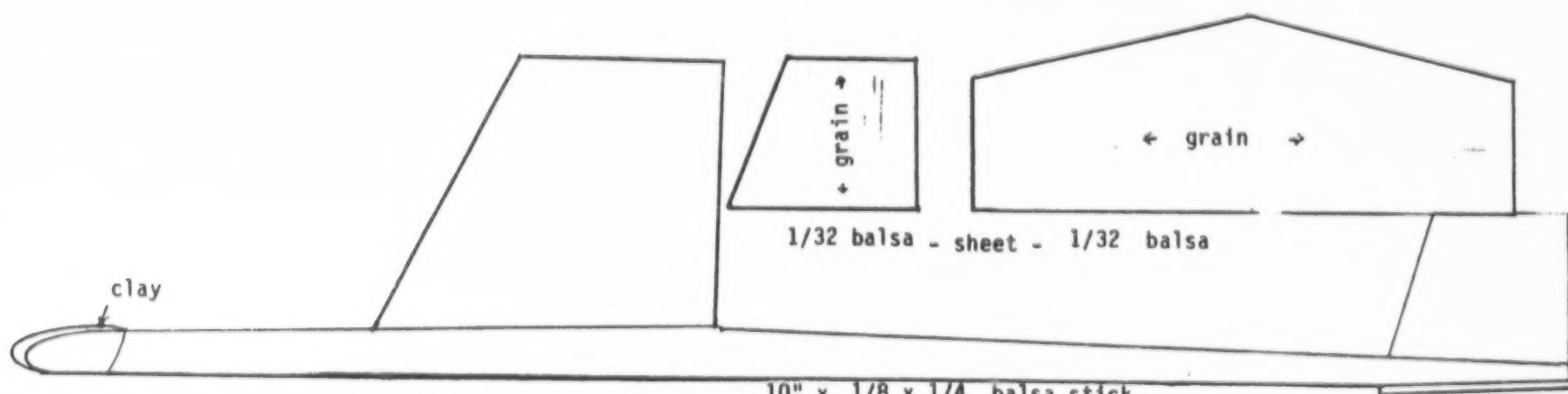
TROUBLE	CAUSE	CURE
Model stalls then dives. 	Poor launch	Easy does it
	Tail-heavy	Add nose weight
	Too much incidence	Launch flatter or give "down" elevator
	Excessive up-thrust	Mount propeller at slight down angle.
	Insufficient turn	Move prop or rudder slightly to one side
Model dives straight ahead 	Insufficient incidence	Launch higher or give "up" elevator
	Nose heavy	Add weight to tail or lighten nose
Model spiral dives to left. 	Thrust problem	Shim prop slightly to the right.
	Excess power	Smaller motor or longer loop in the rubber motor.
	Uncertain cause	Add small amount of weight to right wing tip.
Model spiral dives to right	Same as above	Opposite of above.
Model zooms to altitude, but quickly runs out of power.	Too much power Wrong propeller	Use smaller rubber or longer loop. Try larger diameter, higher pitch, or more blade area.
Model putters around, gains little altitude and lands with many turns left in motor.	Insufficient power	Use larger rubber size and/or sorter loop length.
Model just will not fly, in spite of trying to analyze the problem and making and trying changes.	Construction faults	Take more care next time in construction
	Poor design	Back to the drawing board.



1/32 balsa sheet

Main Wing

front view



1/32 balsa - sheet - 1/32 balsa

10" x 1/8 x 1/4 balsa stick

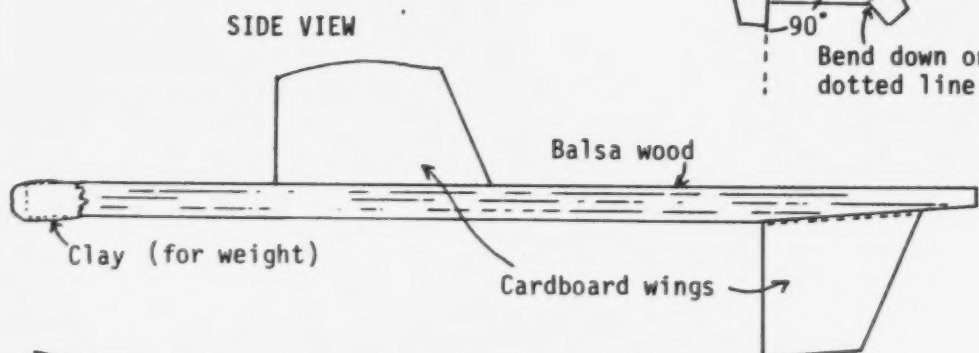
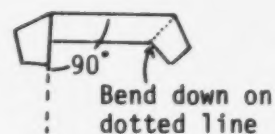
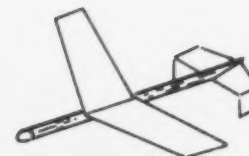
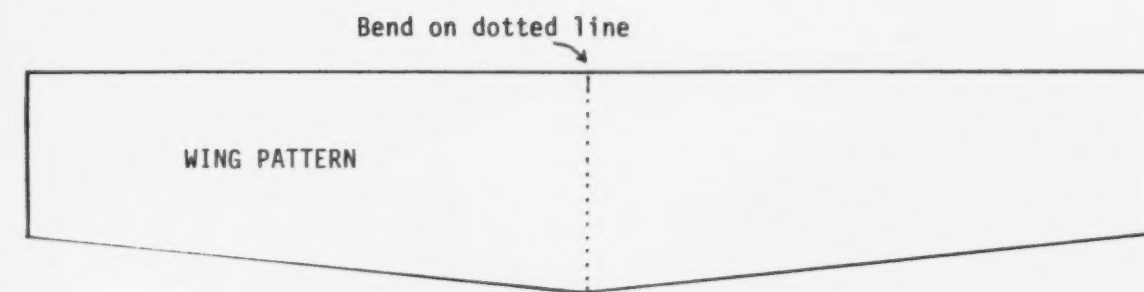
side view

Courtesy Dan O'Malley

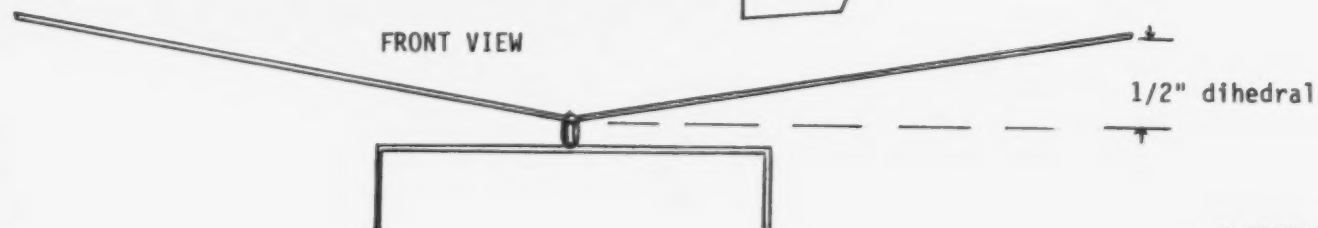
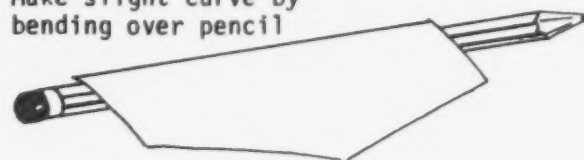
81

80

61



Make slight curve by bending over pencil



GLIDER MODEL - Balsa and cardboard

ELECTRICAL CIRCUITRY/AIRCRAFT LIGHTS

Objectives: To have the students apply principles of circuitry to the wiring of a model aircraft; to become familiar with the clearance light lighting patterns used on aircraft and their meaning.

Materials: Model plane (preferably built by the student); Several feet of light wire (18 gage or less); small flashlight bulbs (at least three per plane though some students may use as many as 7); thin paint in red and green; toggle switches (optional); 2 - 1 1/2 volt dry cells per student; aircraft lighting specs (available from aircraft dealer or company) or a picture of an aircraft showing the lights.

Procedure: 1. Have the students investigate the lighting patterns of the aircraft they plan to use.

2. Have them draw a wiring diagram of the system they propose to use.

3. Have the students install the external lights on their scale model. These may include the wing clearance lights, the tail light, fuselage light or rotating beacon (a flashing light can be used here) and the landing lights.

4. Have the students arrange their wiring so that all of the wires are inside the aircraft and not exposed.

5. Have the students prepare to discuss the position and purpose of each of the lights in their system.

Extension: Depending on the equipment you may have in your classroom, you may wish to have the students compute the ohms and amperage of their circuits comparing the value of parallel vs. series circuits. You may wish the students to investigate the properties of "bi-metal" strips if they choose to use a flashing bulb to represent the rotating beacon.

Note: A number of tiny bulbs are now on the market which will enhance the aesthetic quality of the finished product.



SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Individual or Small Group

TIME:
Several 45 minute periods

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Guided Discovery

CONCEPTS:
Parallel Circuit
Series Circuit
Circuit Breaker

SKILLS:
Construction
Modeling
Interpreting Data
Reading Diagrams

RESOURCES:
BK - F,I
FM - 13,21,22

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

2 or 3-45 minute
periods and
½ day for the trip

TYPE OF ACTIVITY:

Field Trip

TEACHING STRATEGY:

Open Discovery
Guided Discovery

CONCEPTS:

Aeronautics
Airport
Air Traffic Control

SKILLS:

Observation
Recording Data
Questioning
Reading for Information

RESOURCES:

BK - I
FM - 28,29,30,31

Objectives: To understand the various aspects of an airport; to relate studies of aerodynamics to real situations.

Materials: Film, film strips, photographs; Books and pamphlets on the airport; Model airplanes, gliders, etc.

Teacher Background Information: Prior to an airport field trip, several things ought to be covered. Students should have a basic understanding of at least:

- How an airplane flies
- What the parts of an airplane are
- What safety precautions must be taken around airports
- What to expect at the specific airport they will be visiting

It is not difficult to motivate students for a trip like this; but, it can be hard to keep them focused on some of the things it is important for them to learn while they have such fun doing it.

Procedure: (1) Do as many of the activities from the COME FLY WITH ME materials as are appropriate to your particular objectives.

(2) Bring in resource people to talk with students: pilots, weather people, model aircraft builders, etc.

(3) Plan the airport trip with the students. Discuss their past experiences with airports. What did they notice? Have they been to little, middle or large size airports? Similarities? Differences?

(4) Explain which airport they will be visiting. List on the chalkboard what they can expect to see. Your list may have such things as:

- People working at many jobs
- Airplanes--large and small
- Different parts of the airplane
- An instrument panel
- A hanger
- A control tower
- Runways
- The terminal





(5) Formulate questions they feel can be answered by a trip to the airport. Write them on the chalkboard and, later, make a copy for each student to take with them. Encourage each student to add questions to the list throughout the days before the trip.

(6) Arrange for any committees you will need: transportation to the airport; photography; fee collectors; fund-raising; snack for the bus ride--whatever necessary to make the trip both possible and enjoyable.

(7) Get permission slips taken care of.

(8) Go. Enjoy.

(9) Follow up. Have students verbally share their experiences and the answers they found to their list of questions. Ask them to focus on a specific part of the trip and write about it. Make a class collage of pictures and words that depicts the trip. If there are people who need to be thanked, write thank you notes.

Extension: An aerial field trip. This is more involved and demands a lot of planning. It will also be more costly for students since flight time costs money. You and the class may have to engage in some pretty creative problem solving in order to devise ways to defray some of the costs. However, giving the students the chance to fly in a small plane, at slower speeds and with an unimpeded view of the terrain will provide them with the opportunity to see area relationships and orientations that cannot be observed from the ground. Even a half-hour aerial study is well worth the time, effort and cost involved.

Much of what one plans for an airport field trip would be applicable here. In addition, arrangements have to be made for pilots, planes and a specific flight path to cover. Also, some time should be spent discussing appropriate conduct in a small plane and what students can expect to feel, see and hear.

This aerial field trip can be part of the airport field trip or a separate trip of its own. Either way, it is a valuable educational experience and as a culminating activity to a geological study of your area, it is unsurpassed.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual or Small group

TIME:

Several 45 minute periods

TYPE OF ACTIVITY:

Modeling

TEACHING STRATEGY:Expository
Guided DiscoveryCONCEPTS:Rocket Stability
Parts of a Rocket
Static TestSKILLS:Construction
Following Directions
Control of VariablesRESOURCES:BK - A.2a,b;I.1,2
FM - 43,44,58,61,62,66

Objectives: To study the parts of a model rocket; to learn how a model rocket works; to build and launch a model rocket.

Materials: Rocket kit for each student (several easy to build, inexpensive models are available. The authors recommend a model such as the ALPHA, available from Estes Industries Penrose, Colorado 81240. Estes also publishes many model rocketry manuals and activity guides.); a launch system (see activity # 15); extra fine sandpaper; single edge razor blades (one for each two students); rocket engines (at least one per student); igniters; recovery wadding; paint (Optional. Spray paint is easiest to use); activity guides; string; tape; good tacky white glue (It dries faster).

Teacher Background Information: This lesson is designed to allow students to put together many of the concepts and skills learned in previous lessons from this guide and from your regular science classroom activities. You may very well find that several students in your classes have already assembled and flown model rockets. Their expertise can be very helpful to others in the classroom and to yourself if you have not built rockets before. If possible have the students who have built rockets review with the rest of the class what principles of science apply to the flight of their models. You can help them here to put together their presentations.

Procedure: 1. Use the illustration provided to review the parts of a rocket. You may wish to use an assembled model as part of this review. Estes makes a clear plastic model, the "Phantom", which is excellent for a lesson on the parts and structure of a model. The Phantom is identical to the Alpha in size and shape.

2. Do a static test so that the students can see the workings of the engine and the recovery system. See Lesson #'s 12 or 36 for a review of how to set this up.

3. Have the students review the principles of flight for the rocket. Bernoulli's principle may not be as obvious for the rocket as it was for the plane. Newton's laws are

a bit more obvious.

4. Have the students assemble their models after reading the directions through carefully.

5. Test the rockets for stability. First locate the center of balance by resting the body tube of the completed model on your finger. Next, tie a loop of string around the balance point and tape it down. In an open area, swing the model around by the string. If the model is stable, it should fly without tumbling. If the model does tumble, add weight to the nose cone or use larger fins. (This should not be a problem with the models from a kit.) DO NOT FLY A MODEL THAT DOES NOT PASS THE STABILITY TEST.

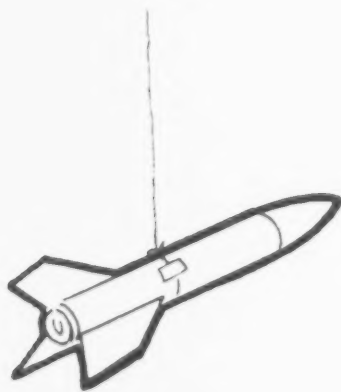
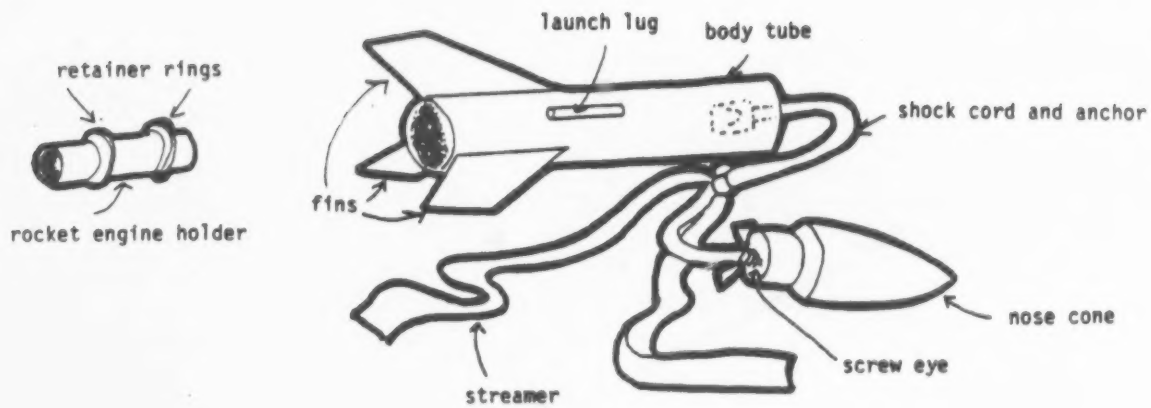
6. Paint the models and allow them to dry. This adds to the durability of the rocket which should last for many launches.

7. Have the students decide how to evaluate the flight of the rocket. How high did it fly? How fast did it go? How close to a point which has been predetermined can you get the model to land?

Extensions: Contact a local amateur rocket club and arrange for a demonstration of larger rockets which these clubs many times make. Have the students build one or more class rockets of the larger variety. Have the students build and test a rocket of their own design. Find out about the manufacture of safe model rocket engines. (The substance in the manufactured model engines is identical to the solid fuel in the boosters used by the Shuttle).



Parts of a Rocket



rocket ready for spin test
complete with rocket engine



spin test

Stability Test

ROCKET NOZZELS

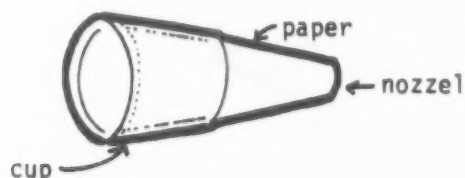
10

Objective: To have students investigate, using a funnel, the effects of a decreasing diameter in a nozzle on the velocity of air passing through it.

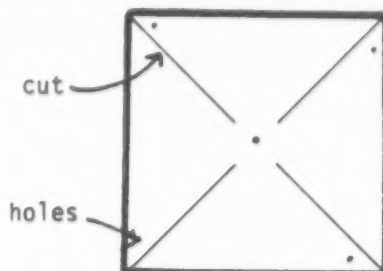
Materials: 4 - 7 oz. styrofoam cups; 3 - 8 1/2" x 11" sheets of paper; scissors; masking tape; single edge razor blade or utility knife; 2 - aluminum pie plates, the throw away kind; ruler; pencil; magic marker; 1 small finishing nail; 1 T pin; 1 coat hanger; 1 stick 1/4 x 1 x 10 - a paint stirrer works well; 1 or 2 small buttons; an air source - a vacuum that can be hooked up to blow is fine.

Procedure: Construct four funnels and two pinwheels using the above materials, as follows:

1. Cut the bottoms out of the styrofoam cups using the razor blade.
2. Roll the sheets of paper into funnels; tape them securely with masking tape and insert into each of three of the cups; tape the funnels to the cups.
3. Cut each funnel in turn to produce openings of 1cm, 2 cm, and 4 cm respectively. The fourth cup should have an opening of 5 cm and will be used without a paper funnel.



4. Measure two squares on the aluminum pie pans, one 6 cm x 6 cm, the other 12 cm x 12 cm. Using the ruler, draw pencil lines corner to corner on each square. Make a small hole in the center where the lines cross. Cut in from the corners, to within 1 cm of the center hole.



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation
or Teacher Demo

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Thrust
Velocity
RPM
Venturi

SKILLS:

Construction
Collecting and
Interpreting Data

RESOURCES:

BK - A.2b;I
FM - 40,41,44,45



5. Make small holes in the corners as shown in the diagram. Bend the corner with the hole into the center and pin the pinwheel to the stick making sure to put a small button between the pinwheel and the stick. (This will allow the wheel to turn freely). Repeat this procedure with the large pinwheel and mount it on the coat hanger. (You can tape the pin to the coat hanger).

6. Paint one fin of each pinwheel with the magic marker to better keep track of rotations.

7. Insert the air hose into each nozzle from the wide end and direct the airflow toward each pinwheel.

8. Have the students observe the rotation speed of each pinwheel when acted upon by each funnel nozzle. Have the students try different distances from the pinwheels but make sure they control this variable for their final data collection.

Discuss the data collected with the students. What happened to the RPM's of the pinwheel when the funnel openings got smaller? Were these results the same when the pinwheel size changed? What was the difference, if any, between the pinwheels? How did a change in distance from the nozzle to the pinwheel effect the RPM's?

Note: Nozzels are thermodynamic devices for converting pressure into velocity according to Bernoulli's equation: pressure energy + velocity energy = constant. Therefore as pressure increases, velocity must also increase. The smaller nozzle creates higher pressure inside the funnel and therefore higher velocity of the air flowing through it. Remember your air source is constant. Of course, this is how great velocities are achieved in a rocket engine nozzle.

Extension: Have the students compute the size ratio of the pinwheels and the nozzels from largest to smallest. (5 to 1 for the nozzels) (2 to 1 for the pinwheels). Can the students predict from their data what the next size of pinwheel or nozzle will produce in terms of RPM?

References: Ned Hannum, NASA, Cleveland, Ohio
Bruce Wilms, Chesterland, Ohio

Objective: To learn and experience examples of Newton's three laws of motion.

Materials: Marble or other small sphere; two meter sticks taped together in a "v" shape; three spring scales; plastic cup; index card; coin; stop watch.

Teacher Background Information: An understanding of the motion of planes and rockets requires a general knowledge of Newton's three laws. The following activities are specific to each of the laws and will help the student see relationships between all three.

Procedure: Newton's First Law... Generally stated as, "Things in motion tend to remain in motion, things at rest tend to remain at rest." The tendency to stay at rest or, once moving, in motion, is called INERTIA. Things move or stop only if acted upon by another force.

To demonstrate:

1. Set a container on a table.
2. Place a card on top of the container and place a quarter on top of the card.
3. Flick the card away with your finger.
4. Did the coin have inertia? What force acted on the card to set it in motion? What force acted on the coin after step 3? (If the card is flipped out of the way fast enough the coin will remain over the container and fall into it.)

Newton's Second Law... "Acceleration of an object increases as the force causing acceleration increases."

1. Prepare a ramp for a marble or other sphere about 1 meter long.
2. Lift one end of the ramp and place a pencil under it.
3. Roll a marble down the ramp and time the roll from one end to the other.
4. Lift the ramp higher. Place a book under the lifted end and repeat step 1.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large or Small

TIME:

60 minute period

TYPE OF ACTIVITY:

Student Investigation
or Teacher Demo

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Newton's Three Laws
Inertia
Acceleration
Action/Reaction

SKILLS:

Observation
Collecting and
Interpreting Data

RESOURCES:

BK - A.1,2a,b;I
FM - 11,40,48

5. Start the marble on a ramp with one end pencil high. As the marble starts out, lift the end of the ramp higher. What was the effect on the speed of the marble?

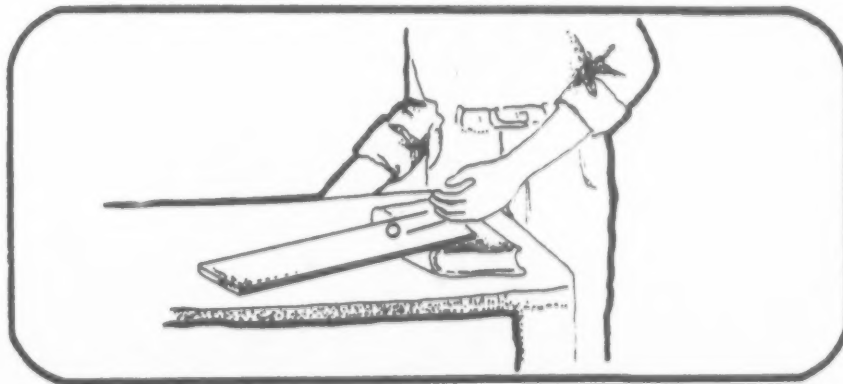
6. Compare the results of the first two experiments. What was the result? What was the force that was acting on the marble? How was it increased? What was the effect of this increase?

Newton's Third law... "For every action there is an opposite and equal reaction."

1. Take two spring scales and hook them together.
2. Have two students pull on the scales in opposite directions. Record the readings from both scales.
3. Place a third scale between the other two. Record the readings from all three. What were the differences in the readings for the two scales? When three scales were used? (The readings should all be the same in each experiment.)

Extensions: Have the students apply the principles of Newton's Laws to the description of ...

1. A plane taking off and climbing to 2000 feet while accelerating to 120 miles per hour.
2. A three stage rocket launched into orbit around the Earth then sent on to the moon. Which of Newton's laws are being applied in each case and at what point are they being applied?

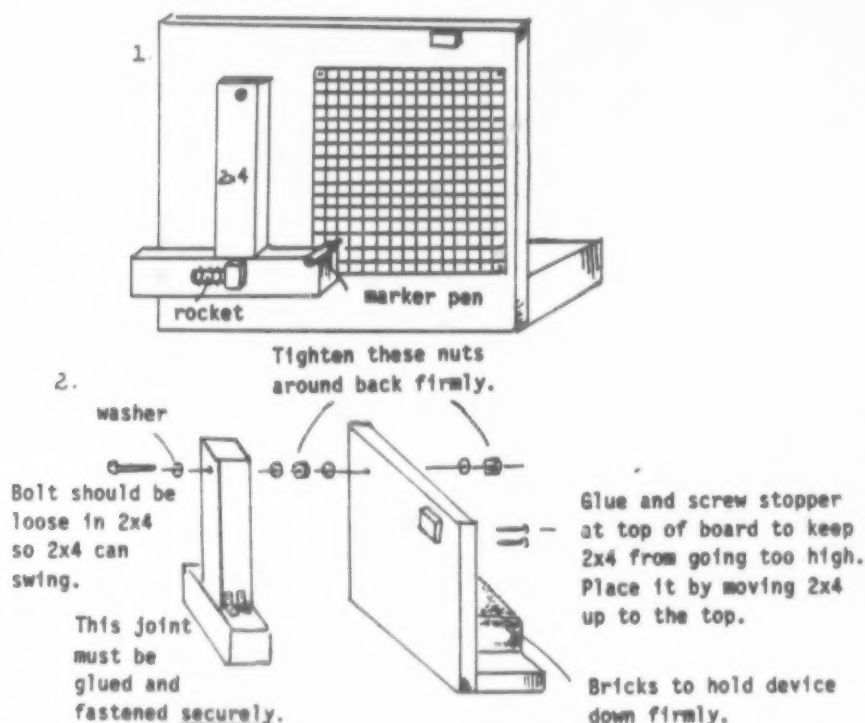


CONSTRUCTING A "THRUSTOMETER"

Objective: To help students understand the difference in thrust power by constructing a device to measure thrust.

Materials: three 2 x 4's (for base and swinging arm); one piece of pressed board or plywood for upright; small piece of wood for stopper, 4 brackets; small piece of wood to block front of engine; bolt; 4 washers; 2 nuts; wire; drill; graph paper; bricks; various size model rocket engines.

Procedure: In order to answer questions about how much thrust a particular rocket engine has, the students can construct a device that will measure various engines for model rockets. The first diagram shows what a homemade "thrustometer" looks like, and the second diagram shows how to make one:



****Note** that the 2 x 4 is free swinging on a bolt fastened securely to the plywood back.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small or Large

TIME:
2-60 minute periods

TYPE OF ACTIVITY:
Student Investigation
or Teacher Demo.

TEACHING STRATEGY:
Expository
Guided Discovery

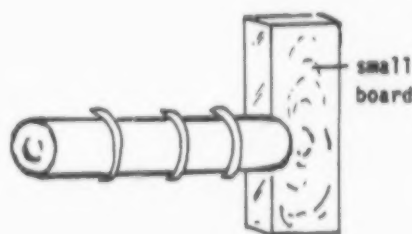
CONCEPTS:
Thrust
Power Curve
Action Reaction

SKILLS:
Measurement
Interpreting Data
Experimentation

RESOURCES:
BK - A.2b;I.1,2

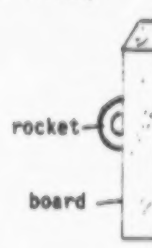
The rocket holder must also be firmly constructed and attached. Look at these sketches and be sure you understand the need for each part of this rocket holder.

DETAIL OF ROCKET (Front side view)



Remember there is an explosive charge in each rocket that is used to blow off the nose cone. **LEAVE THE END OF THE ROCKET ENGINE UNCOVERED!**

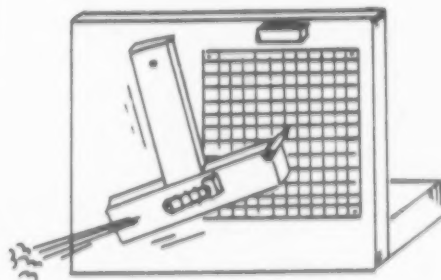
DETAIL OF ROCKET (Front view)



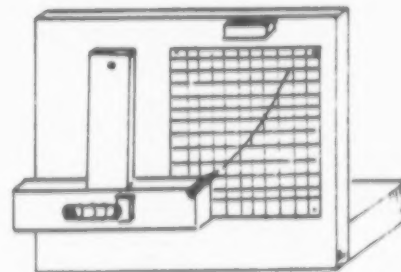
Note that half of the front of the rocket is butted up against the wood.

Attach a sheet of graph paper and a marker pen to the thrustometer and move the swinging 2 x 4 to see if the pen moved smoothly and if the graph paper is properly placed.

When all is ready, attach a small engine securely in the rocket holder and get students a safe distance away. Then field test the thrustometer.



Pen tracing path on graph paper. Note the small wooden stopper at the top of the graph paper.

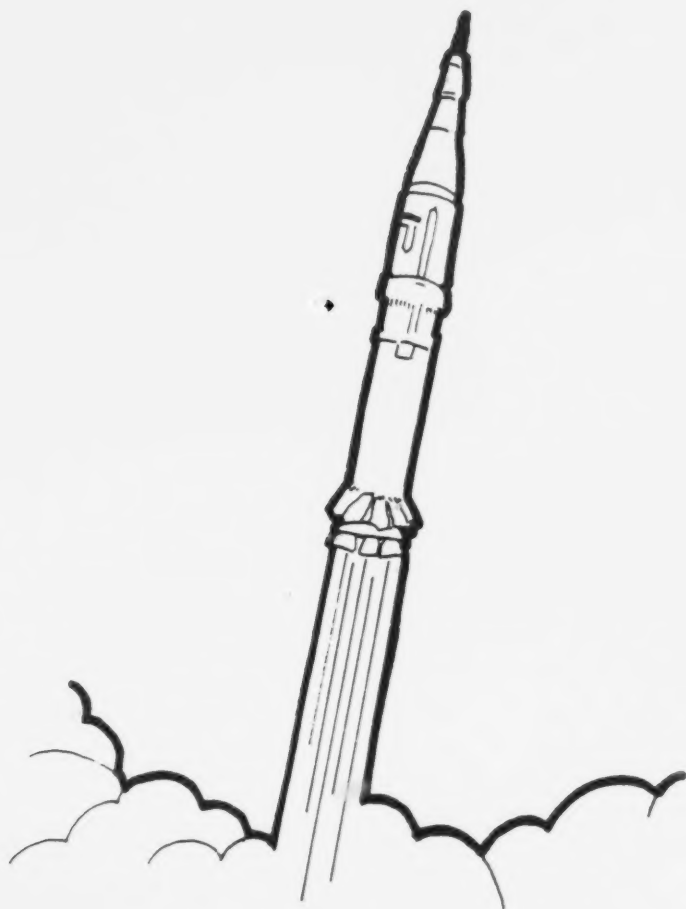


Remember to always place the graph paper in the same position for each test.

Thrustometer from OPEN MATH, Knaupp & Knauff, Arizona State Univ.

If the 2 x 4 arm doesn't move, the wood is too heavy for the engine. If it quickly swings to the stopper, then there isn't enough weight on the arm. What is needed for the arm is an optimum weight so that a small engine will move it a little and a big engine will move it close to the top.

Once you have found the proper weight for the arm, set off several model rocket engines and calibrate the amount of thrust as shown on your graph paper.



RECOVERING SPACECRAFT WITH PARACHUTES

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual and Large

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Deceleration
Braking

SKILLS:

Modeling
Recording Data
Interpreting Data

RESOURCES:

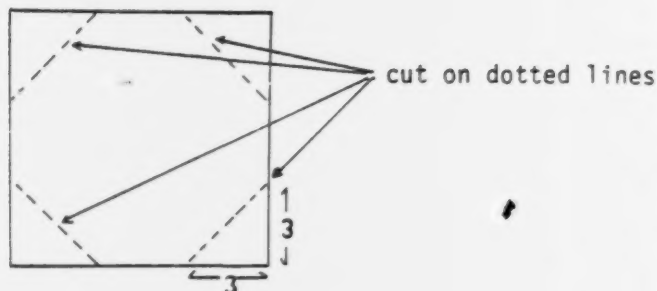
BK - A.2a,5b;I.2
FM - 51,55,58,61,62

Objective: To demonstrate that the parachute system used is dependent upon the weight of the vehicle.

Materials: Set of gram weights up to one gram (washers may be substituted); three pieces of cloth one foot square; ball of string; scissors; ruler.

Teacher Background Information: Spacecraft orbiting the Earth are returned by means of braking rockets or retro-rockets which are fired in a forward direction and thus slow the craft down counteracting the inertial movement away from the Earth. The Apollo spacecraft did not use retro-rockets, however. Parachutes were used at the proper time to slow the descent. Scientists are also experimenting with paragliders and parachutes to return parts of spacecraft to earth and to land on other planets.

Procedure: Have the students make octagons out of the three pieces of cloth. This can be done by cutting four triangles off the corners, 3" x 3". For easier identification, have the students mark the pieces of cloth in the middle with a red marker, indicating the weight attached as follows: "1/4," "1/2," and "1." Have them tie a 12" piece of string to each of the eight corners of the octagons. Tape the ends of the eight strings together on the one marked "1/4" and attach a one-quarter gram weight to the parachute and fold it neatly. Repeat with the one-half and the one gram parachutes and weights.



Go outside and drop the one-quarter weight parachute from a measured height. Have students record the time it takes for the parachute to descend. Repeat twice for an

average and then do the same with the one-half gram and the one gram weighted parachute.

Once your students have the data, go back to the classroom and discuss:

1. What did the students observe about the velocity with which the weights returned to earth?
2. As the weight of the vehicle increases, how must the chute system change?
3. Can the size of the chute be increased forever? Explain.
4. Did the parachutes return to the same place each time? What force acts on a parachute that makes its destination difficult to predict?



Adapted from educational materials available from NASA Kennedy Space Center Teacher Resource Room

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual and Large

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

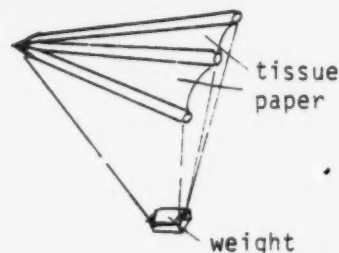
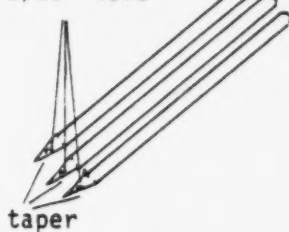
Guided Discovery

CONCEPTS:Lifting Body
DescentSKILLS:Modeling
Experimenting
Collecting DataRESOURCES:

BK - A.1;B.2;I

Objective: To demonstrate the way paragliders work.Materials: Three 1/4" dowels 12 inches long; heavy tissue paper or wrapping paper; tape; scissors; knife; electric drill with a 1/8" or 1/16" bit.Teacher Background Information: Parachutes have been used in the recovery of manned spacecraft and to slow jets landing at high speeds. The parachute systems for recovering space vehicles have been very workable but parachutes do present the problem of maneuverability. NASA has been experimenting with a paraglider which would be maneuverable and create lift. This device could be used to land space vehicles at a predetermined area.Procedure: Using the drill, make a small hole in one end of each dowel, about 1/4" from the end. Using the knife, taper the ends with the holes in them. Tie the three ends together so they form a fan shape. Cut pieces of the paper to fasten over the dowels, making sure you allow some slack so the glider has two billowing sections. Tie a string to the end of each dowel and one to the front section so a weight can be tied to the strings.

1/16" hole



Take the class outside and experiment with various weights tied to the paraglider. How much weight can it hold and still provide a safe descent? Have students discuss what variables have to be considered in constructing a paraglider.

Extension: Ask the students to construct a paraglider capable of returning an egg to the ground safely from a 30 foot height with little or no protective wrapping around the egg.

Adapted from educational materials available from NASA Kennedy Space Center Teacher Resource Room

WIRING A LAUNCH SYSTEM

Objective: To apply basic circuitry concepts to the production of a practical, electrically controlled launch system for model rockets.

Materials: (For each system to be wired) several feet of bell wire; electrical tape; two alligator clips (small); two - 6 volt light bulbs; two light bulb holders; 2 toggle switches or one toggle and a push button type switch; wood to construct a box to hold the wiring or an electrical hobby box of the type available at an electronics supply store; screwdriver; wire strippers; (optional) soldering gun and solder.

Procedure: You may proceed in one of two ways for this activity, depending on time and how open-ended you wish to be.

1 - a. Have the students investigate the requirements of a launch circuit and the availability of diagrams which may help them. A source may be a local model rocket club, a company that produces models such as Estes in Penrose, Colorado, or a local hobby shop.

1 - b. Use the diagram which follows this lesson plan.

2. Have the students interpret the diagrams to produce their circuit.

3. Test the circuits and use to actually launch a model produced in lesson # 9.

4. Have the students discuss the need for the safety features found in most circuits and have them build one into their own if they have not.

Extensions: Have the students find and report on information about the actual launch control systems used by NASA. If you have a science club or a group of advanced students, they may wish to investigate and build a remote, perhaps radio, controlled launch system.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
Several 45 minute periods

TYPE OF ACTIVITY:
Student Activity

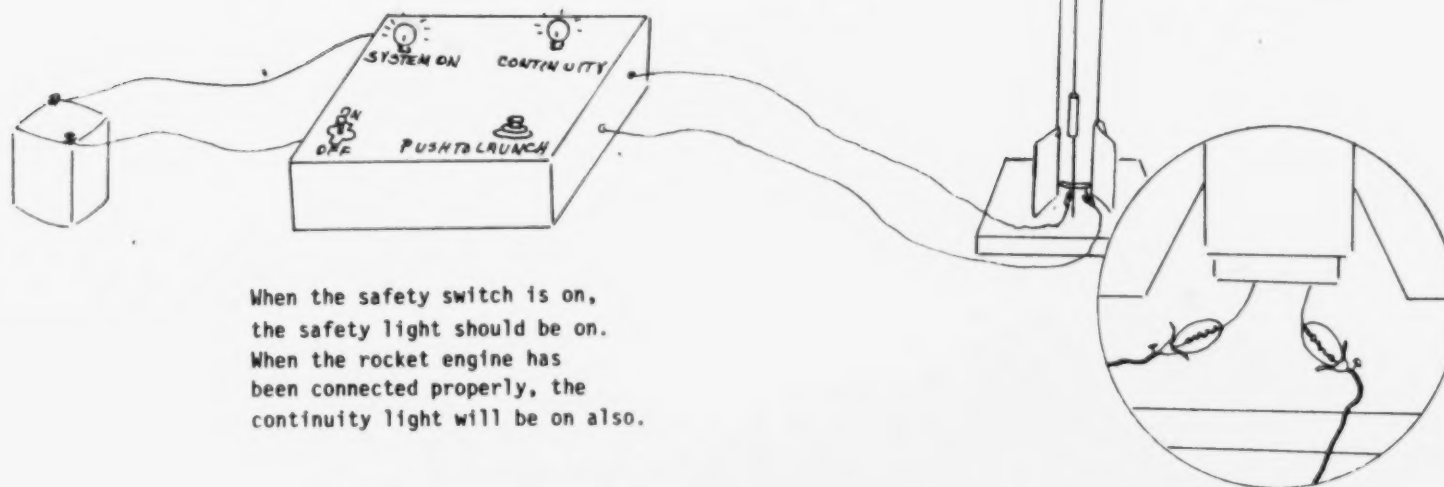
TEACHING STRATEGY:
Guided Discovery
Expository

CONCEPTS:
Circuitry
Remote Control

SKILLS:
Construction
Reading and Interpreting Diagrams

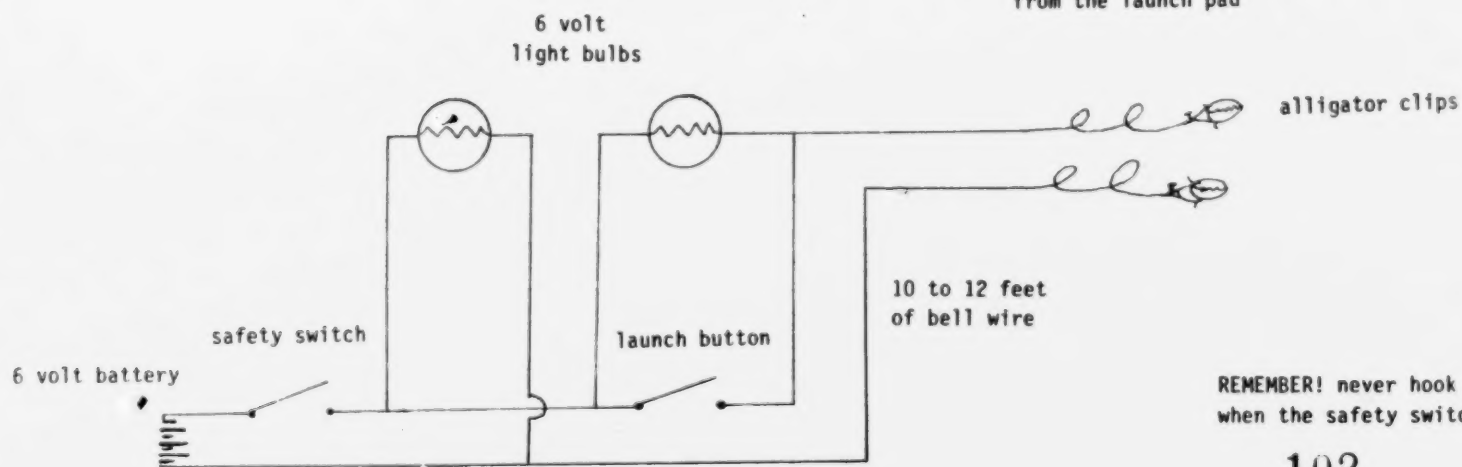
RESOURCES:
BK - I.1,2

Wiring a Launch System



When the safety switch is on,
the safety light should be on.
When the rocket engine has
been connected properly, the
continuity light will be on also.

stay back about 20 feet
from the launch pad



REMEMBER! never hook up a rocket engine
when the safety switch is turned on.

MODEL ROCKET CONTEST



16

Objectives: To apply skills and concepts learned about rocket flight to the solution of a specific challenge in a model rocket contest; to apply the safety rules of model rocket flying during actual launches; to apply the concept of Control Of Variables to achieve an approximation of a specific objective with a model rocket.

Materials: Students with model rockets; a launch system for every 5 to 10 students; tape measure; two or three red flags and stakes to nail them to; stop watch; data scoring sheet; a big field and a nice day.

Teacher Background Information: A FUN culmination to the building and testing of models is to actually fly them. A contest with specific tasks to prepare for is a way to have students "put it all together." The following rules and contest descriptions are just two of several ideas for rocket competition. If you want more information, the Estes company in Penrose, Colorado has a booklet, contest forms and award certificates available. If you have Science Olympics in your area, the directors may have suggested rules for competition. You may wish to use the school competition as a way to prepare for a larger meet between schools from many areas. A model rocket group in your area may be willing to assist you.

Procedure: The rocket contest will consist of TWO events. Individuals or teams may enter one or both events.

A TEAM may consist of no more than FOUR contestants. The winning team score for any event shall be the sum of the points for each individual launch. Team members must launch two rockets within the launch window provided for them during the contest. If a team member's rocket fails to launch after two tries the rocket will be disqualified. Another rocket may not be substituted. A team may enter one or both events.

AN INDIVIDUAL may enter one or both events. Awards will be made for each event. An individual's rocket will be disqualified if it fails to achieve launch after two tries.

ALL TEAMS AND OR INDIVIDUALS MUST REGISTER FOR THE ROCKET COMPETITION PRIOR TO THE DAY OF COMPETITION so that launch planning can take place.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

$\frac{1}{2}$ DAY

TYPE OF ACTIVITY:

Game
Simulation

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

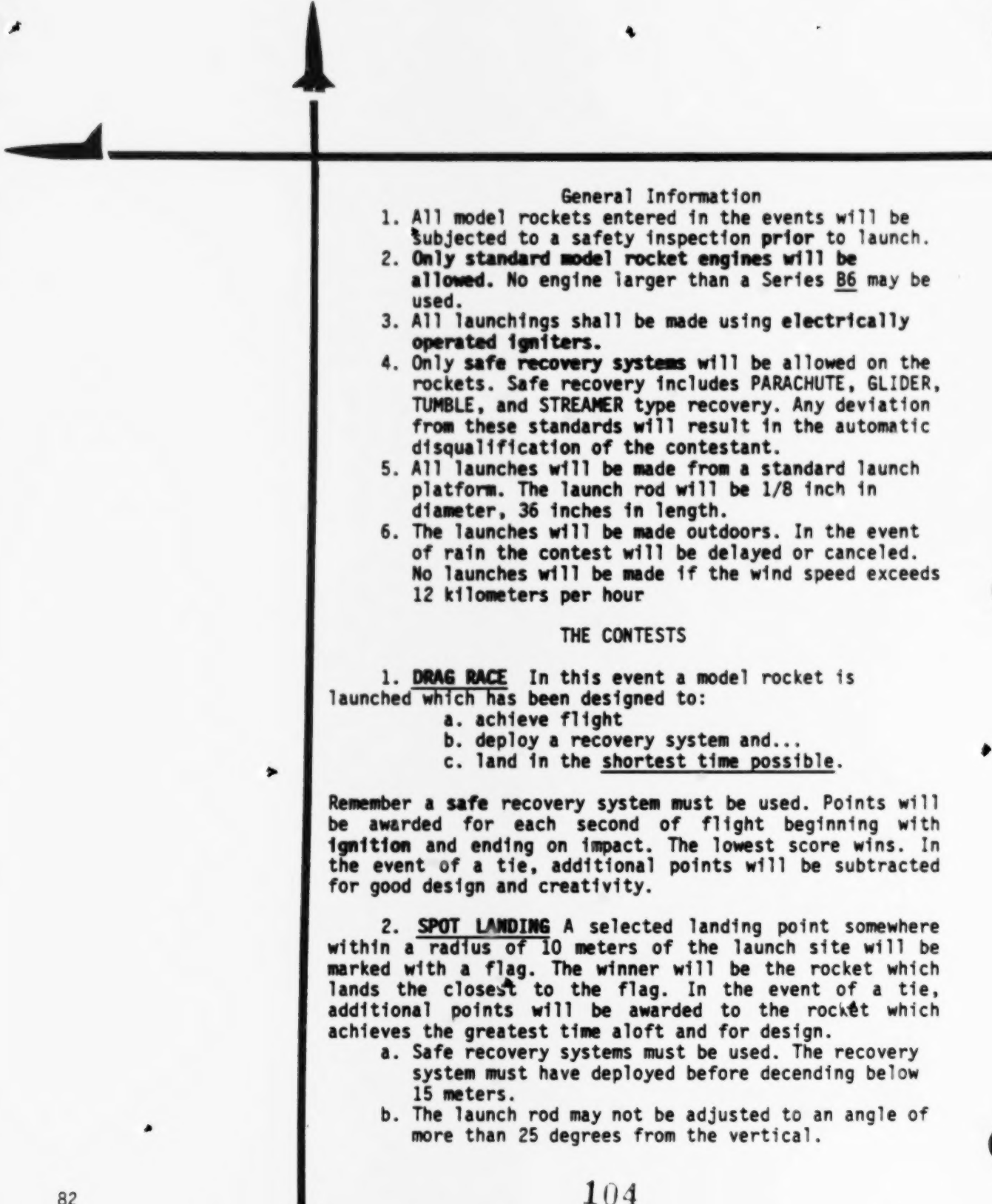
Launch Safety
Altitude
Trajectory

SKILLS:

Control of Variables
Following Directions

RESOURCES:

BK - I.2



General Information

1. All model rockets entered in the events will be subjected to a safety inspection prior to launch.
2. Only standard model rocket engines will be allowed. No engine larger than a Series B6 may be used.
3. All launchings shall be made using electrically operated igniters.
4. Only safe recovery systems will be allowed on the rockets. Safe recovery includes PARACHUTE, GLIDER, TUMBLE, and STREAMER type recovery. Any deviation from these standards will result in the automatic disqualification of the contestant.
5. All launches will be made from a standard launch platform. The launch rod will be 1/8 inch in diameter, 36 inches in length.
6. The launches will be made outdoors. In the event of rain the contest will be delayed or canceled. No launches will be made if the wind speed exceeds 12 kilometers per hour

THE CONTESTS

1. DRAG RACE In this event a model rocket is launched which has been designed to:
 - a. achieve flight
 - b. deploy a recovery system and...
 - c. land in the shortest time possible.

Remember a safe recovery system must be used. Points will be awarded for each second of flight beginning with ignition and ending on impact. The lowest score wins. In the event of a tie, additional points will be subtracted for good design and creativity.

2. SPOT LANDING A selected landing point somewhere within a radius of 10 meters of the launch site will be marked with a flag. The winner will be the rocket which lands the closest to the flag. In the event of a tie, additional points will be awarded to the rocket which achieves the greatest time aloft and for design.
 - a. Safe recovery systems must be used. The recovery system must have deployed before descending below 15 meters.
 - b. The launch rod may not be adjusted to an angle of more than 25 degrees from the vertical.

Objectives: To demonstrate methods of cooling a spacecraft or aircraft traveling at high speed in the atmosphere; to learn the concepts of regenerative and ablation cooling.

Materials: Two ring stands or tripod supports; two burner triangles; two small paper cups; two candles; water; heavy plastic cup; plastic cup which has been dipped in melted wax repeatedly until a thick ($\frac{1}{4}$ " or more) coat of wax has built up on the outside; matches.

Teacher Background Information: The problem of dissipating the heat build-up caused by friction when a plane or spacecraft travels through the atmosphere has been a hard one to solve. Three main ways of cooling are used now. One is ablation. Ablation makes use of a melt away covering to carry the heat away with it. The covering is sacrificed and enough must be put on a craft so that it does not all melt before the craft slows to a speed where heat is no longer a problem. This cooling technique was used on spacecraft through the Apollo missions.

Another technique is that of regenerative cooling. This method makes use of a super cooled fluid passing through pipes near the surface which is being heated. The fluid absorbs the heat and carries it away from the surface. This method is used in some planes and in many rocket engines where the fuel, liquid Oxygen and/or Hydrogen, is circulated around the rocket nozzle and preheated before being burned.

The third method uses material which actually stores the heat and releases it slowly so that nearby surfaces do not overheat quickly. The Space Shuttle uses such a material.

Procedure: (1) Set up two ring stands or tripods and place a triangle on each ring. Place a candle under each. Fill one paper cup and place it on one of the stands, above the candle. Place an empty cup above the other candle. Light the candles. What did you observe happen? Why do you suppose that is? (The empty cup will burn quickly. The filled cup will not get hot enough to ignite because the water carries the heat away or stores the heat.) This is similar to the Shuttle tile function.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
45 minutes

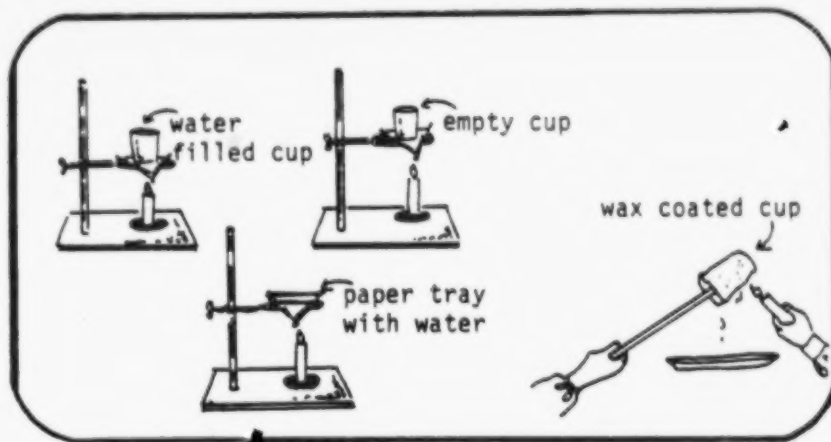
TYPE OF ACTIVITY:
Teacher Demonstration

TEACHING STRATEGY:
Guided Discovery

CONCEPTS:
Ablation
Regenerative cooling

SKILLS:
Observation
Inference

RESOURCES:
BK - A.2a,5e;B.2
FM - 42,46,53,63



(2) Take another cup and place a small amount of water in the bottom or fold an index card into a flat tray shape with a small amount of water in the tray. Heat the cup or card the same way as before. The water will boil carrying the heat away in the steam. Of course, the card will not ignite until the water has all been evaporated. This is an example of regenerative cooling.

(3) Hold the wax covered cup up with a stick over a plate. Light one of the candles or a propane torch. Aim the flame at the cup and observe. What happens? Why do you suppose the cup behaved the way it did? (The wax melts away carrying the heat with it.) If you try a control experiment with an uncovered cup, what do you suppose will happen? Try the same experiment with the heavy plastic cup. What similarities or differences were there between this cup and the wax coated cup? USE A WELL VENTILATED AREA. This is an example of ablation.

Extensions: Try to obtain other materials which will respond to ablation. A chemistry teacher may be able to suggest some plastics or other substances which will work. It is very difficult to get a sample of a Shuttle tile but you might try. The Space Mobile demonstrators bring a piece with them when they visit schools for workshops; you may be able to see a demonstration of the tile's ability if you have such a visit. The tiles, by the way, must be cooled by air conditioning within 15 minutes of touchdown or the heat "soaks" through to the Shuttle skin which is only aluminum.

SATELLITES IN ORBIT

18

Objective: To demonstrate two forces acting on a satellite.

Materials: Five metal washers; 40" length of string; large wooden spool.

Teacher Background Information: A satellite remains in its orbit because of two physical phenomena: inertia and gravity. Inertia is the tendency of a moving body to continue to move in a straight line unless something interferes to change its motion. Gravity pulls a spacecraft into orbit around the Earth. Satellites are not slowed by friction because there is almost no atmosphere to cause friction in space.

Procedure: 1. Push the string through the hole in the spool. Tie four of the washers to one end of the string and tie one washer to the other end.

2. Ask the class to observe what happens when you hold the spool in your hand and whirl the single washer in a circle. (The four washers should hang down from the bottom of the spool.)

3. Ask the students why this happens? (The weight of the four washers and the string connecting them with the single washer prevent the single washer from flying off in a straight line as it circles.)

4. Ask the class to determine what the single washer represents (an orbiting satellite) and what the string represents. (The gravitational pull of the Earth.)

5. Ask what would happen if the single washer were able to fly loose from the string? (It would fly out and away in a straight line.)

6. Ask why a spacecraft does not fly straight into space? (Because of the Law of Gravitation plus retrorockets, attitude thrusters and navigational devices using the laws of motion.)

7. Ask students to think about why satellites do not slow down and stop? What happens when students run and slide on the ice? What happens when they

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
50 minutes

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Guided Discovery

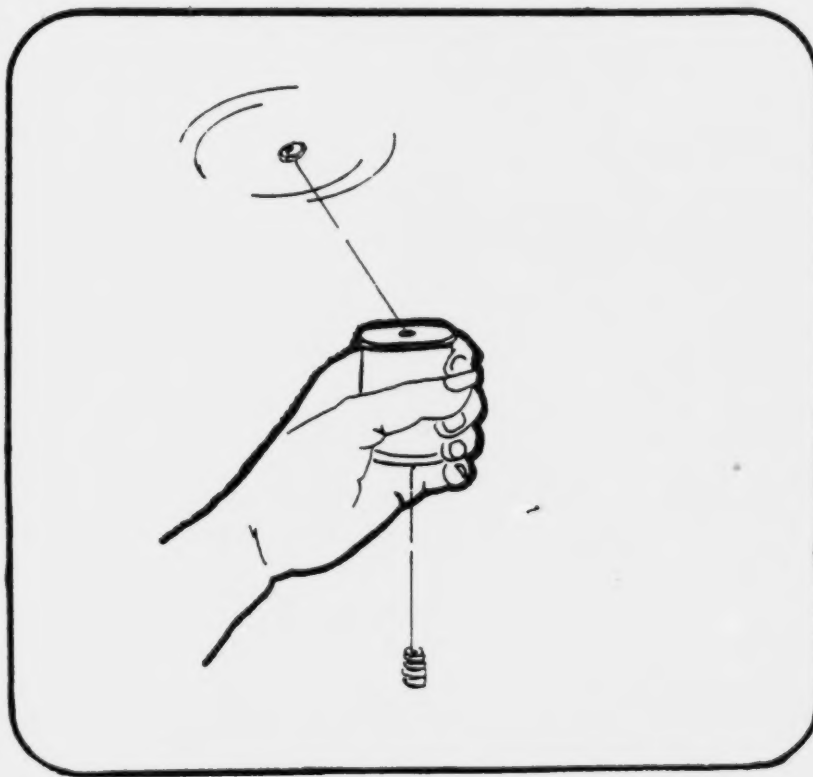
CONCEPTS:
Orbit
Inertia
Gravity

SKILLS:
Observation
Interpreting Data

RESOURCES:
BK - A.2a,4a;D.5a;I
FM - 33,35,66

throw a ball? What is it that causes the skater and the ball to slow down? (Friction) Why doesn't the satellite slow down? (In space there is very little for a satellite to rub against since space is almost empty.)

Extension: For further demonstrations of the everyday experiences which might illustrate straight line inertia of motion ask your students to think about how water is thrown off the wheels of a passing automobile. To demonstrate, stand a bicycle upside down and have a student turn one of the wheels while another pours a few drops of water onto the tire. You can also lay the bicycle on its side and lay small objects on the sidewall of one tire. (Make sure they are small and soft, like an eraser, for example.) Spin the wheel and the objects fly off in a straight line. Ask your students what they think may cause that to happen.



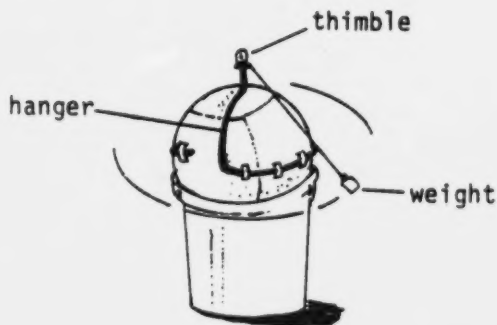
OVAL ORBITS

Objective: To introduce the concept of orbit and to observe that objects can orbit in both oval and circular orbits.

Materials: Basketball; coat hanger; tape; two or three feet of string; weight (lead sinker works well); pail; thimble; softball.

Teacher Background Information: Most earth satellites have orbits which are oval shaped. The oval pattern is determined by the angle of insertion into space. The point farthest from the earth is called apogee. The point in the orbit nearest to the earth is called perigee.

Procedure: Before class period, place the basketball in the pail; bend the coat hanger and tape it to the ball so that it is in an upright position. Attach the string to the thimble and place it on top of the upright hanger. Attach the weight to the other end of the string.



When the class arrives, get the softball and take the students outside. Standing at a marked line, have a student toss the ball out gently. Mark the spot where it lands. Have another student throw it out a little harder and mark the landing spot. Last, have someone throw the ball as hard as he/she can and mark the spot where the ball lands.

Ask the students to speculate about whether anyone could throw a ball hard enough so it would fall over the horizon and miss the earth altogether. Ask the group to

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
50 minutes

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Guided Discovery

CONCEPTS:
Orbit
Angle of Insertion
Apogee
Perigee

SKILLS:
Observation
Interpreting Data
Experimentation

RESOURCES:
BK - A.1,4a;D.4;5



think about such things as "Why spacecraft have to be launched with more powerful launch systems in order to reach orbit in space as opposed to suborbital flights," or "What sort of orbital configuration do spacecraft fly in as they orbit?"

When the class is back in the classroom, explain to them that the ball in the bucket represents the earth and the weight represents a satellite. Ask a student to tap the weight away from the ball and observe how and where it turns. Have the student carefully push the weight away at different angles. At different speeds. While it is in motion. What does the student notice? Are there differences in the shapes of the orbits? Are some elliptical? Circular? How can the type of orbit be determined?

Discuss apogee and perigee with the students. Explain the smallest distance the weight (satellite) is from the ball (earth) is called perigee of the orbit and the farthest distance is called the apogee.

Give each of the students the chance to experiment with the ball and the weight. By the end of the lesson, the students should be able to address these questions:

1. How is the type of orbit determined? (By the angle of insertion and speed.)
2. What kind of orbit occurs when the weight is pushed out from the surface of the ball? (An elliptical orbit)
3. What must be done to achieve a circular orbit? (Tap the weight away from the ball and then tap again or start the orbit with the weight already away from the ball.)
4. What is the farthest distance the satellite orbits from the earth called? (apogee)
5. What is the shortest distance the satellite orbits from the earth called? (perigee)

Extensions: Have the students do the experiments in the next activity to explore circular orbits further and to explore the effects of gravity and inertia on orbits.

Adapted from educational
materials available from
NASA Kennedy Space Center
Teacher Resource Room

INERTIA & GRAVITY - CIRCULAR ORBITS

Objectives: To explore the forces necessary to achieve a circular orbit using a model; to learn in what direction, relative to gravity, inertial force must be applied to achieve a circular orbit.

Materials: Two ropes or cords about 2-3 meters long; a box or chair; the basketball set up from the Oval Orbits activity # 19.

Teacher Background Information: To achieve a true circular orbit, a space vehicle after launch must use rocket thrust aimed at right angles to the center of gravity of the earth. The following activity demonstrates the phenomena in two ways: first, using a demonstration with two ropes and a weighted box or a chair and, second, with the basketball and string set-up from the previous activity.

Procedure:

- (1) Tie two ropes to a box or chair.
- (2) Have two students hold the ends of the ropes and move away from the box or chair at right angles to each other.
- (3) Have the two pupils pull straight back slowly on the ropes. Note the direction the box or chair travels relative to the students.
- (4) Have one student, and then the other, pull harder on their ropes. How is the direction of the box or chair changed?
- (5) Try angles other than 90° and note the angle of the path the box or chair takes.

Explain to the students that one rope represents gravity and the other rope represents inertia from the rocket.

NOTE: To achieve a specific direction somewhere between the direction of thrust and the direction of gravity the two must be at right angles. Too small an angle will result in a trajectory which will carry the satellite (box or chair) back to earth. Too great an angle will result in the satellite losing speed and then falling back to earth unless it can achieve enough speed (40,000 kph) to break away from gravity.

(6) Using the basketball set-up from the previous activity, "Oval Orbits," have the students

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

50 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Orbit
Inertia
Gravity

SKILLS:

Observation
Experimentation

RESOURCES:

BK - A;D
FM - 18,48,66

explore what is necessary to achieve a circular or near circular orbit with the weight.

(7) Have them tap the weight into an elliptical orbit and tap again at right angles to the ball.

(8) Try other angles and observe the results.

Extension: Investigate orbital and escape velocities. Have students note how much inertia an object must have to achieve orbit. How fast must it go to break away from orbit all together?

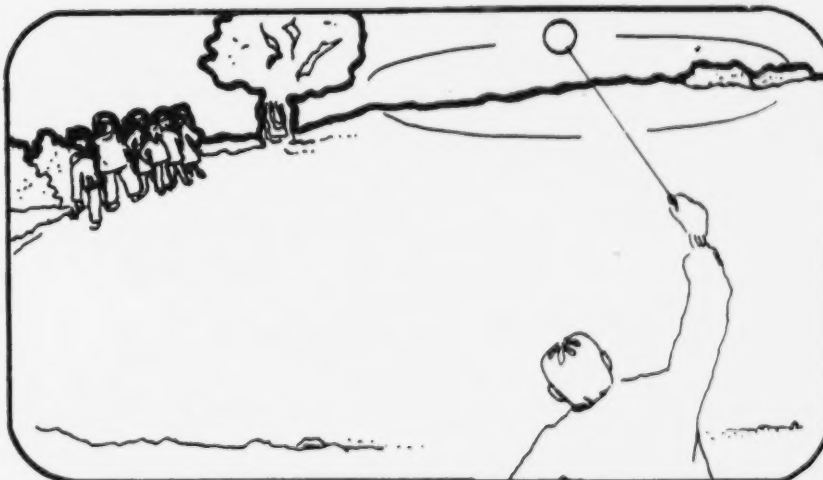
THE FOLLOWING DEMONSTRATION SHOULD ONLY BE DONE IN A LARGE AREA SUCH AS A PLAYGROUND.

Have the students tie a 2 meter long thread around a mushball or other heavy soft ball. Use light thread as you want it to break. Have a student stand well away from any other students or buildings and swing the ball around him/her to achieve orbit. Have the student swing faster until the ball (spacecraft) breaks the string (gravity.) Observe the path the ball takes once it has broken "the pull of gravity."

Remember, keep the students back far enough so that the ball hits the ground first before it can be caught.

How is the ball and string like a spacecraft and gravity?

What was necessary to "break" the pull of gravity?



Objectives: To distinguish between weight and mass; to develop techniques of finding mass when there is no weight; to build equipment to determine mass when a balance will not work.

Materials: For each group of three students: 1 hacksaw blade; 1 small "c" clamp; 1 small bolt with two nuts to fit the hole at the end of the hacksaw blade; several washers of the same mass; a stop watch; data sheet; a table or chair to fasten the "c" clamp to. (You can build a stand as in the diagram and weight it with bricks).

Teacher Background Information: The weight of an object is always a measure of the pull of gravity on that object (the attraction of one mass to another). On the Moon, objects weigh 1/6 of what they do on the Earth. In space, some 300 kilometers above the Earth, objects weigh about 1/3000 of what they do on the surface. (Essentially, they are nearly weightless.) A 210 pound astronaut would weigh about 1 ounce. Many of the experiments done on the health of astronauts required finding their mass while in space. Mass is measured in grams. Grams are defined as the mass of one cubic centimeter of water. You are measuring the amount of matter in a given space when you measure mass. The amount of astronaut does not change while in space from that while on the Earth or on the Moon. His or her mass would be the same - only the weight (attraction of gravity) would change. So, how can mass be measured when there is no weight???

Procedure: 1. Attach a hacksaw blade to the leg of a chair or a stable platform of some kind with a "c" clamp.

2. Fit a bolt through the hole at the opposite end of the blade and secure it with a nut.

3. Attach a washer to the bolt and secure it with the other nut.

4. Pull the blade to one side and release.

5. Have a student count the number of oscillations of the blade while,

6. another student keeps time with a stopwatch.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

45 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Weight
Mass

SKILLS:

Construction
Collecting and
Interpreting Data

RESOURCES:

BK - A.1,2a,5a;I
FM - 48

7. Have another student keep track of the swings per minute on the data sheet.

8. Add washers to the blade, one at a time until several bits of data have been collected.

9. Make a calibration chart of the results by graphing the data.

Note: The hacksaw blade oscillations are independent of gravity and are dependent on the elasticity of the metal. The same number of swings would be recorded on the Moon or in space.

FIND THE MASS OF AN UNKNOWN

10. Place a small ball of clay on the mass tester.

11. Measure the number of swings per minute and refer to the calibration chart to determine the mass in washers.

12. Find the mass of the washers and compute the mass of the clay in grams.

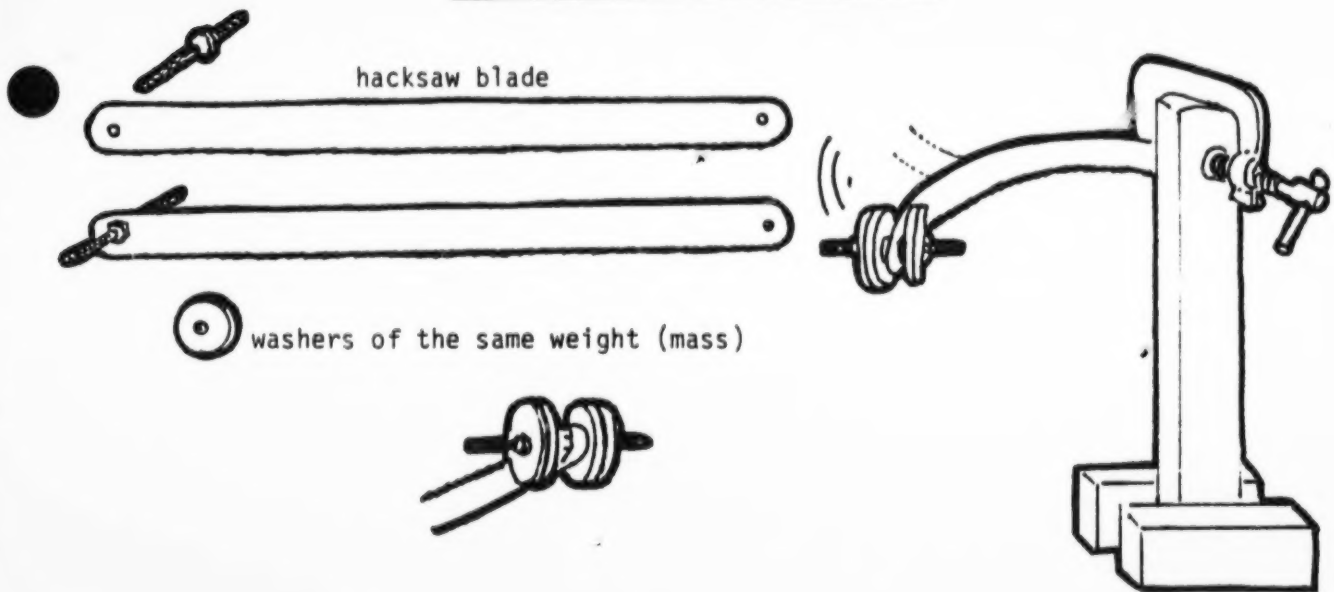
13. Place the clay on a balance and check your calculations to see how accurate your measurements were.

Note to the Teacher: You may wish to tie this lesson in with one on the arbitrary nature of systems of measurement.

Extensions: The astronauts use a device similar in operation to the simple device the students produce in this lesson to measure their mass in space. Have the students find out more about it by investigating some of the experiments performed on Skylab.



INSTRUCTIONS FOR MASS MEASURER...



MASS CHART

Washers

Swings/Minute

Objectives: To help students understand the difficulty of conventional reference points in navigating in space; to understand how the earth's magnetic field can be used to orient satellites in space; to illustrate how tracking stations can locate a satellite in space.

Materials: (For Activity 1 - The Problem) Thread or string, paper stars (stickers are easy); tape or tacks; shoe box; paper; pencil.

(For Activity 2 - The Solution) Bar magnet; dry cell battery; paper; light or bell; iron filings; compass; copper wire.

(For Activity 3 - Another Solution) Transistor radio.

Teacher Background Information: Tracking provides information by continuously reporting the location of a satellite, a probe that is going deep into interplanetary space, or of small rockets that will penetrate space on an up-down path of, perhaps, only a few hundred miles. Location is important for the scientist-experimenter because he/she has to know precisely where the spacecraft is at a particular point in time so an event measured by the spacecraft can be correlated, for example, to its position to the Sun, the Moon, or Earth. The scientist has to know its position to send it guidance information, to send it commands to make observations and to transmit data or change flight plans.

Long range rockets have guidance systems which work on the principle of comparing present position with point of destination. In traveling to the moon the astronauts have to navigate by using the Earth and the Moon as frames of reference. Tracking stations can also locate a satellite exactly.

Procedure: (Activity 1) The first activity should help to orient the pupils to the problems of space navigation.

1. Before class, suspend thread from the top of the shoe box. Hang the paper stars on the end of the threads. Hang them in such a way as to take on the shape of the Big Dipper and place the cover on the box. Make several holes in the sides of the box for the students to look through. In addition, cut a hole for more light to enter the box in one end. (See illustration, top of next page.)

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

3-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

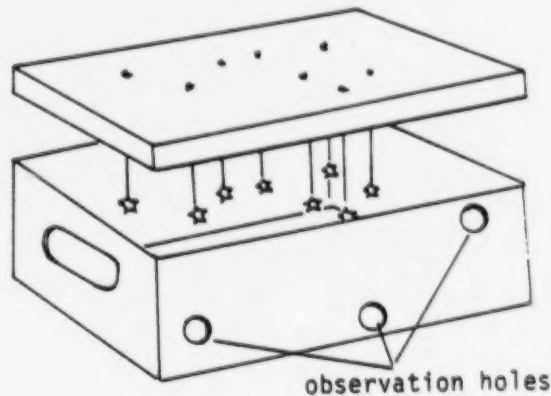
Magnetic Field
Tracking
Frame of Reference

SKILLS:

Observation
Inference
Recording Data
Experimentation

RESOURCES:

BK - A.1,2a,c,4a,c;I
D.2
FM - 50



2. Ask the students to look through one of the holes. In what position are the stars? Have students sketch their position on a piece of paper.

3. Have the students move. What do they observe now? Resketch the stars.

4. Why doesn't the Dipper have its familiar shape when observed through the holes? Discuss the notion that when we travel in space the appearance of the constellations will be different. This will affect an astronaut's bearings on direction when flights to the planets become a reality. Make certain students understand the appearance of the constellations in space depends upon the position that they are viewed from. (You can demonstrate the same thing by hanging string, with stars attached, from the ceiling of your classroom and having the students move about the room noting the difference in configuration from where they happen to be observing.)

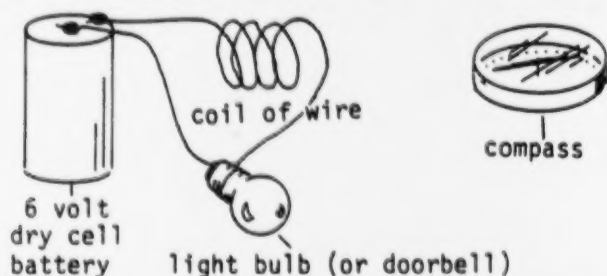
5. Encourage pupils to experiment with frames of reference such as: throwing the ball to someone who is running, plotting the paths of a child on a ferris wheel as seen by friends on the ground, friends on the wheel and

the child herself, etc.

(Activity 2) 1. Have a student place a magnet under a piece of paper and sprinkle iron filings evenly over the paper.

2. Have student gently tap the paper until the filings form a pattern over the magnet. Have another student hold a small compass over the pattern and observe where the needle points in relation to the lines of force. Where does it point? How does this help to orient a satellite? If we put a magnet in a small satellite near the earth, we could point it in outer space. How?

To see how, set up the following apparatus: Attach a large dry cell battery (4x volt) by a coiled copper wire to a light bulb or doorbell. Move a compass up to and through the coil to see where the needle points.



With a current loop around the base of a Tiros satellite, space scientists can point or orient it in outer space.

(Activity 3) 1. Have a pupil turn on the transistor radio and tune it in on a station. Turn the radio around and listen to the strength of the signal received.

2. Change the direction of the radio. Discuss the relationship between the location of the radio station and direction of the transistor radio. How are radio transmitters on a satellite used to aid in locating and tracking a satellite?

Extension: Have the students research the global system of tracking stations and communications networks.

Have a "ham" operator in to tell the class about monitoring satellites and talking to astronauts in space.

Adapted from educational materials available from NASA Kennedy Space Center Teacher Resource Room

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

45 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Traction
Surface Conditions
Lunar Rover

SKILLS:

Experimentation
Collecting Data
Modeling

RESOURCES:

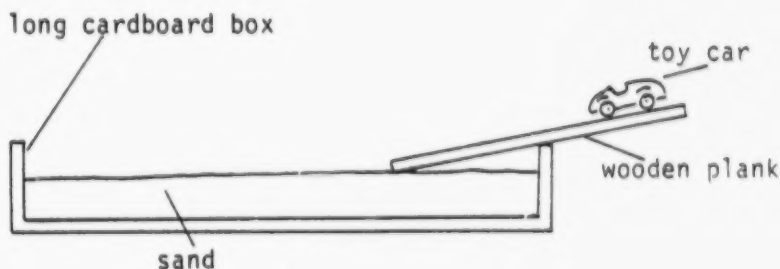
BK - A.5b;C;D.5c3
FM - 51,52,60

Objectives: To help students understand the problem of getting people around on a loose surface such as the Moon's; to apply that understanding to the construction of a land rover.

Materials: LONG cardboard box filled with dry, fine sand; Wooden plank; Toy car.

Teacher Background Information: The moon rover, that dune-buggy, electric car that astronauts used on the moon, provides great motivation for students to explore the question of transportation on the surface of the Moon. If you ask students the question, "What would it be like to live on the Moon?" one of the responses would likely involve intra-moon transportation systems. And, as we live in a car society of self-contained, self-powered vehicles, capable of going anywhere at the driver's whim, the car might very well be the most common image in students' minds. This concept and this interest can lead to all sorts of experimentation and quantitative data collection.

Procedure: Set up the long cardboard box with the dry sand.



Ask the students to observe what happens when you send a toy car down the plank onto the surface of the sand. Ask



them to describe what they know of the Moon's surface and how the astronauts overcame the problem of the loose surface.

1. Instruct the students to break up into small groups of 3 or so to discuss what sort of rover they could construct that would move over the loose sand with ease. Explain they will be asked to place their "rover" on the end of the wooden plank and to measure the distance the device moves across the sand.

2. Give the groups a few days to work out what they want to do and time to construct the rover. See if any of the groups ask to test the rover in your sand. If they ask, of course, let them!

3. On the appointed day, have students bring in their rovers, set up the experiment and ask each group to run their rovers.

4. Collect the measurements and graph the results. Discuss with the class how each of the groups went about solving their problem. How did they arrive at consensus for the final vehicle? Did they pre-test before the big day? Did they have to rework any ideas?

Extension: Have the students discuss the idea of mass transit on the Moon. How might they go about adapting some of the vehicles they came up with? Why might it be very important to have mass transit rather than, or along with, "cars" that move people a few at a time?

As they visualize a moon colony, what does it look like, as far as transportation goes? What are some of the particular reasons for specific kinds of transportation on the moon colony? Are there any kinds of transportation they might need on the Moon that we don't necessarily need here on Earth?



LIFE SCIENCE



CONTENTS

"We step out of our solar system into the universe seeking only peace and friendship, to teach if we are called upon, to be taught if we are fortunate."

Kurt Waldheim, Secretary
General, U. N., 1977

LIFE SCIENCE OBJECTIVES

1. TO UNDERSTAND THAT DIFFERENT CONDITIONS THAN THOSE OF EARTH EXIST IN THE NEAR VACUUM OF SPACE.
2. TO RECOGNIZE THE POSSIBILITY OF EXPANDING HUMAN BEING'S ENVIRONMENT THROUGH THE EXPLORATION OF SPACE.
3. TO IDENTIFY BASIC LIFE NEEDS OF HUMANS AND TO EXPLORE WAYS TO PROVIDE FOR THOSE IN SPACE.
4. TO FUTURIZE ABOUT HUMANS LIVING IN SPACE AND INVENT HYPOTHETICAL SPACE COLONIES.
5. TO CONSIDER THE PSYCHOLOGICAL NEEDS OF PERSONS WHO ARE ISOLATED FOR LONG PERIODS AND TO INVENT WAYS TO PROVIDE FOR THOSE NEEDS.
6. TO CONSIDER THE ENVIRONMENTAL IMPACT OF FLIGHT IN THE ATMOSPHERE.

LESSONS

- | | |
|--|--|
| 24. TAKING A BIT OF HOME UP WITH YOU | 35. WHAT'S ON YOUR MIND? |
| 25. GASP! | 36. AIRCRAFT AND THE ENVIRONMENT |
| 26. GET ME OUT OF HERE | 37. SPIN OFFS FROM SPACE |
| 27. FRED, WE NEED A TREE IN HERE | 38. GETTING SPACEY AT THE AMUSEMENT PARK |
| 28. SOLAR HEATING AND COOLING | 39. PHYS ED IN SPACE |
| 29. PLANT GROWTH IN SPACE | 40. DR. FREUD GOES TO SPACE |
| 30. WATER WATER EVERYWHERE BUT NOT A DROP TO DRINK | 41. IS ANYBODY OUT THERE? |
| 31. SPACECRAFT DECONTAMINATION | 42. MOON ROOM FOR RENT - BEAUTIFUL VIEW |
| 32. A PEANUT CALORIMETER | 43. SPACE COLONIES AND THE FUTURE |
| 33. A RUN TO THE MOON | 44. THE SHUTTLE GOES TO THE FAIR |
| 34. YOU MAKE MY BLOOD BOIL | |

TAKING A BIT OF HOME UP WITH YOU

Objective: To reinforce the concept of a "closed ecological system" and relate this concept to life on a spacecraft.

Materials: Three bottles or jars with tight covers; aquarium snails or guppies; aquarium water.

Teacher Background Information: The cabin of a space vehicle must be constructed so that it provides all of the conditions necessary to sustain life. Both the physical and the mental health of those on board must be considered. This experiment deals with the need for oxygen production and the removal of carbon dioxide from the cabin atmosphere.

Procedure: Fill the three bottles with aquarium water. Into each jar place the following: Jar A - aquarium plants; Jar B - snails or guppies; Jar C - plants and snails or guppies. (Make sure there are enough plants and light for photosynthesis or the organisms will die.) Now, add more aquarium water to each jar so that they overflow slightly. Cap each jar tightly and allow them to stand for a few days.

Observe the jars after two days. Look for any changes and note any differences in behavior of the organisms. Continue this observation and recording for several more days.

Relate each jar to possible conditions in a space vehicle. What provisions were made in each jar for life support? What factor did time play in this experiment? What is meant by the term "closed ecological system"? What provisions would need to be made for astronauts on board the shuttle for a two week stay in space? How does what you must consider for the astronauts relate to the closed system in the jars? How has NASA dealt with these concerns on the Shuttle or in the Skylab?

Teacher Note: You may wish to use this as an introduction to the several activities which follow. The lessons cover environments in space for people and deal with oxygen, food, air pressure, temperature, etc., all necessary components of a closed environment such as a space vehicle.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Expository and
Guided DiscoveryCONCEPTS:Closed Ecological
System
OxygenationSKILLS:Experimentation
Observation
InferenceRESOURCES:BK - A.5;C;I
FM - 65,66

Adapted from educational
materials available from
NASA Kennedy Space Center
Teacher Resource Room

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

60 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Guided Discovery
ExpositoryCONCEPTS:Anoxia
Closed Environment
Rate of UseSKILLS:Experimentation
Collecting and
Interpreting DataRESOURCES:BK - A.1,5;C
FM - 65,66

Objectives: To measure the rate at which oxygen is used in a closed environment; to understand the importance of knowing the rate at which oxygen is used in a closed environment.

Materials: 250ml flask or bottle; pipe cleaners; glass tube; ink; 1 one - hole rubber stopper to fit the flask; calcium hydroxide (lime water); small animal(s)-mouse or crickets or cockroaches, etc. (The smaller the organism, the slower the movement of the ink.)

Procedure: Place a small animal(s) into the bottle along with a pipe cleaner soaked in calcium hydroxide. Stopper the bottle with the stopper containing a short glass tube. It is important to seal the bottle well or air leaking in may spoil the experiment.

DO NOT PLACE THE GLASS TUBE IN THE STOPPER WITH YOUR BARE HANDS. PLACE GLYCERIN ON THE TUBE FIRST TO ALLOW IT TO SLIDE INTO THE STOPPER MORE EASILY. WRAP THE TUBE WITH A TOWEL IN CASE IT BREAKS WHEN INSERTING IT.

Place a small drop of ink on the open end of the tube outside the bottle. Wipe off the excess. Observe the movement of the ink marker inside the tube. Calibrate the tube every minute until it enters the bottle. Use different numbers of animals in the flask or try different kinds of organisms. Calibrate the tube for each kind of organism. Can your students predict what the rate will be when several organisms are placed in the flask based on their data for a few or one? Why would it be important to know the rate at which an animal uses oxygen? Relate this to people on board a space craft.

Extensions: (1) Have the students explore the symptoms of anoxia (lack of oxygen) in humans. Think of ways to create oxygen on board a space craft.

(2) Have the students do Activity #84 - "Oxygen Production" in the K - 6 COME FLY WITH ME materials before they do this activity if you feel they need more background.

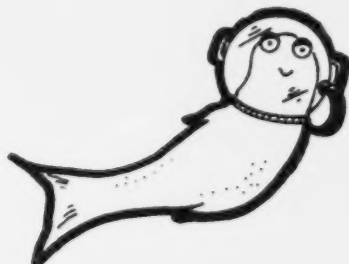
Objective: To understand the importance of providing a low Carbon Dioxide environment for the inhabitants of a spacecraft.

Materials: Several Guppies; a small aquarium or other container for the Guppies; a 100ml flask or glass; straws; Bromo-thymol-blue (BTB [optional]).

Procedure: Have a student blow for about a minute into a glass of water through a straw. Introduce a Guppy to the glass. Observe the behavior of the Guppy for about 10 - 15 seconds. Remove the Guppy and place it in the original container. Review with students that BTB is an indicator for acid. Add two drops of BTB to a clean glass of water and have a student again blow through a straw into the water. Discuss with the students what main gas is exhaled when breathing. Relate the exhaled gas to the behavior of the Guppy in the water with the high CO_2 content.

Teacher Note: The Guppy would not survive for long in the water with the high Carbon Dioxide content. The CO_2 causes the water to turn acidic and the guppy may try to jump out or will swim violently around the glass trying to get out. If the Guppy is removed after only a short time in the bad water, it will survive. Do not wait more than 10 or 15 seconds though before replacing it in the good water. The BTB should turn to a light green, then yellow and eventually nearly clear as the concentration of CO_2 gets higher in the water. The students should conclude that a high concentration of Carbon Dioxide is not conducive to keeping an animal alive.

Extension: See the next lesson to review a method to remove excess Carbon Dioxide from the air we exhale.



SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
30 minutes

TYPE OF ACTIVITY:
Demonstration or
Student Investigation

TEACHING STRATEGY:
Guided Discovery
Expository

CONCEPTS:
Acidification
Indicator Solutions
Gas Solubility

SKILLS:
Observation
Inference
Experimentation

RESOURCES:
BK - A.1,5;C;I
FM - 59,65

FRED, WE NEED A TREE IN HERE! CABIN ATMOSPHERE AND CARBON DIOXIDE REMOVAL

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
45 minutes

TYPE OF ACTIVITY:
Teacher Demonstration

TEACHING STRATEGY:
Guided Discovery

CONCEPTS:
Solubility of Gases
Air Purification

SKILLS:
Observation
Inference
Reading for Data

RESOURCES:
BK - A.1,5;C;I
FM - 52(Apollo 13),
65

Objective: To understand that CO_2 can be removed from exhaled air.

Materials: Three 250ml flasks or bottles; glass tubing; rubber tubing; three two - hole stoppers to fit the containers; lime water - $\text{Ca}(\text{OH})_2$.

Procedure: Assemble the glass tubing, rubber stoppers, and rubber tubing as shown in the diagram.

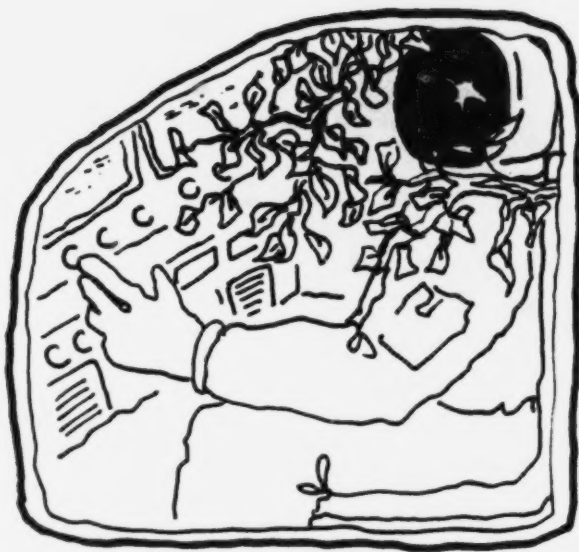


SAFETY NOTE: NEVER ATTEMPT TO PUT GLASS TUBING THROUGH A STOPPER WITH BARE HANDS. PUT GLYCERIN ON THE TUBING FIRST WHICH WILL ALLOW IT TO SLIP INTO THE STOPPER EASILY.

Add lime water to each of the containers so that the end of the long glass tubing in each will be covered. Be sure the short tube is clear of the liquid. Stopper the bottles and have a student blow through one end of the rubber tubing. The exhaled air will pass from one container to the next until it is expelled from the far end of the apparatus. Observe the color changes in the containers. How do you account for the changes in the contents of each flask? Are all the containers the same now? What may have happened to cause them to be the way they are now?

Discuss with the students whether or not this system for the removal of Carbon Dioxide is a practical one for use on a spacecraft.

Extensions: Have the students explore NASA data to see how Carbon Dioxide is removed (scrubbed) from the air in a space vehicle. Explore the question: Why don't we have to remove CO₂ from the atmosphere on Earth? Relate the removal of Carbon Dioxide to the process of photosynthesis in green plants. Plants have also been used on board space vehicles for the production of Oxygen.



Adapted from educational materials available from NASA Kennedy Space Center Teacher Resource Room

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

2-60 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Open or
Guided Discovery

CONCEPTS:

Heat Reflection
Absorption
Solar Cooling

SKILLS:

Hypothesizing
Experimenting
Interpreting Data

RESOURCES:

BK - A.1,5;D.5b;I
FM - 65

Objective: To set up an experiment to determine what colors and or materials reflect the most heat away from an enclosed container.

Materials: Three small corrugated cardboard boxes; several colors of construction paper or paint (be sure to include white and black); aluminum foil; three thermometers; clear sheet of acetate or plastic (overhead projection acetate is fine); tape.

Teacher Background Information: One of the major obstacles to living in space is temperature control. The temperatures inside a spacecraft may reach several hundred degrees if some method of cooling is not put into place. The early Skylab missions used a slow rate of rotation and shading as techniques to help cool. The Lunar Lander used gold foil on the outside to reflect heat away from vital components. Of course, air conditioning units are also carried aboard spacecraft as well as in space suits. However, if a spacecraft must remain in one place for any length of time, some method of assisting the cooling process must also be used.

Procedure: Have the students speculate on how to go about testing for the cooling characteristics of several materials and colors on a closed container. Tell them to use containers which are about 15cm x 25cm x 5 to 10cm.

If you wish to make this a bit more directed activity, you may have them do the following: Construct three boxes which have a small hole punched in one end to allow the thermometer to be inserted. Place a sheet of colored paper on one side of the box and face this to the sun for about 30 minutes. Have the students record the temperature inside the box every 10 minutes. Try placing acetate over the colored paper and record the results including any differences in temperature from plain paper. Try foil and or several other materials recording the results each time. Try lining the inside of the box as well as the outside with different materials. After all the trials, have the students graph their results and present their conclusions as to the best reflective material for heat dissipation.

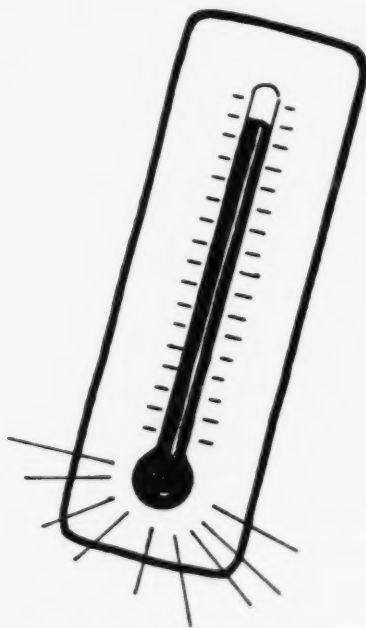
During the 10 minute periods the students are waiting to record temperatures in the container, have them use another thermometer to measure the temperature near buildings, rocks and other structures where the sunlight falls at different angles or, in some cases, not at all. Have the students relate these readings to the effect of the angle of the sun on temperature. How might the angle of the sun affect the temperature inside their box?

Extensions: (1) If you have access to an electric spit from a barbecue or a turntable device, have the students measure the temperature inside a container mounted on the device and compare the results with the other trials.

(2) See other solar experiments in the Earth Science section of this manual.

(3) The students may wish to use their data to construct a device to retain as much heat as possible for a solar energy heat source or cooker.

(4) Check out Activity #83 - "Shielding Against Heat and Cold" in the K - 6 COME FLY WITH ME materials.



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Individual

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery
Expository

CONCEPTS:

Tropism
Artificial Gravity
Stimulus/Response

SKILLS:

Experimentation
Collecting and
Interpreting Data

RESOURCES:

BK - A.5c,e;B.1,2

Objectives: To show tropism in plants and to show the effect of artificial gravity on the growth of plants.

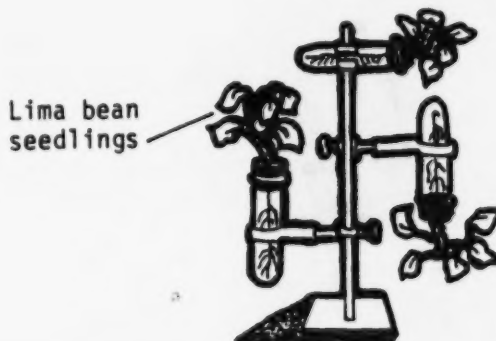
Materials: (Activity 1) Lima bean seedlings; three test tubes; test tube clamps and ring stand; water; stoppers with hole.

(Activity 2) Several kinds of seeds - lima beans, corn, radish, etc.; glass jars; paper toweling.

(Activity 3) Phonograph turntable; several soilless containers with plants (You may use the same setup as in Activity 1).

Procedure: (Activity 1) Ask the students what they know about root growth and stem growth on Earth. Ask them to predict what might happen to the responses of roots and stems in a weightless environment. Now have them set up the following experiment to verify their predictions about the responses of roots and stems on Earth.

Fill three test tubes with water. Carefully place the root end of a lima bean seedling through the hole of a stopper so that the stem end is at the top of the stopper. Seal the hole with a little wax or clay. Place the stopper into a test tube. Repeat this procedure for the other two plants. Clamp the test tubes onto a ring stand as shown in the diagram below. After a few days have the students check to see what responses the roots and stems have exhibited. How are the stems growing? The roots? What stimulus do the roots seem to respond to?

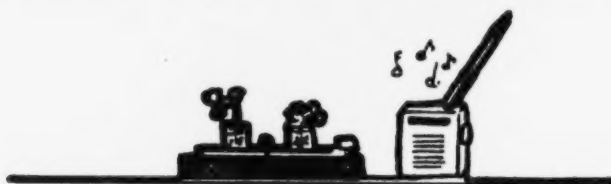


(Activity 2) Let the students germinate seeds between a paper towel and the inside of a glass container. After germination, note the position of the roots and stems. Have the students turn the apparatus on its side and observe the response of the roots and stem after a few days. What happened to the direction of these? Try turning the containers different amounts every few days. What happens to the roots and stems?

You can compare the effect of gravity on several kinds of plants if you would like by doing the following: Prepare six containers as in activity 2, placing three bean, three radish and three corn seeds in each container. After germination, turn two containers on their sides and two upside down. Leave two alone as a control. Observe the response of the stems and roots after several days. The students by now should be able to conclude that roots and stems respond to gravity. You may want to try some of these in the dark, if the students have not already suggested this, to control for the response to light. Have the students hypothesize what the response of roots and stems might be in a weightless environment.

Teacher Note: Experiments on the Skylab growing wheat seeds showed that geotropic plants were a bit confused by the weightlessness of space. Roots and stems grew in all directions. It was apparent that if plants were to be grown in space that a system for providing artificial gravity would have to be employed. If some of your students have been to Epcot Center, ask them if they saw the experiments in the Plant World pavilion. Several experiments are underway there for NASA.

(Activity 3): Attach soilless containers similar to those in activity 1 to the turntable of a phonograph. Observe the growth of roots and stems now. Does the spinning motion of the turntable produce an artificial gravity? Do the plants behave in the same way as they did in activity 1? How are they the same or different?



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

Several short periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Expository
Guided Discovery**CONCEPTS:**Filtration
Bacteria Culture
Water Purification**SKILLS:**Experimentation
Collecting Data
Interpreting Data**RESOURCES:**BK - A.5;C.1,2a
FM - 65

Objectives: To understand that pure water must be carried or manufactured on board a space craft; to understand that there are ways of purifying water through filtration and distillation making it possible to use waste water.

Materials: (Activity 1) 2 liter jug and water; (Activity 2) flask, one hole stopper, glass tube, rubber tubing, tray of ice cubes, beaker; (Activity 3) sand, lamp chimney, cloth, rubber band, dirty water; (Activity 4) aquarium, water, aquarium charcoal filter; (Activity 5) filter paper, funnel and support, 20 grams of aluminum chloride $[AlCl_3]$, dilute sodium hydroxide $[NaOH]$ solution, beaker.

Teacher Background Information: There are a number of reasons that water is a vital consideration while traveling in space. Water is needed most urgently for drinking. It is also needed for reconstituting some of the food carried on board, for hygiene, and for cooling. Because of the duration of flights and because the equipment through which water passes must be kept free of residue, the water used must be free of bacteria and precipitates. Clogged equipment or a culture of bacteria in the drinking water could spell disaster for the astronauts.

Procedure: (Activity 1) Fill a CLEAN jug with tap water and let it stand for several weeks. Observe, taste and discuss the problems associated with storage of water over extended periods of time.

(Activity 2) Distill water by boiling it in a flask fitted with a one hole stopper containing a glass tube and a length of rubber tubing. Lay the tubing across a tray of ice cubes and collect drops of water from the end of the tubing. Discuss the physical changes that water goes through during the distillation process (evaporation and condensation). Examine the residue in the flask from which the water was distilled. Why might it be a good idea to use distilled water in a steam iron or in a storage battery? Why might a space vehicle need to use distilled water? Where on earth might it be necessary to be able to distill water for drinking

purposes? (Anywhere materials need to be removed from the water which would make the water undrinkable, ie., on a ship in order to use sea water.)

(Activity 3) Demonstrate the filtration of water by placing about 5 centimeters of fine sand in a lamp chimney which has a piece of cloth fastened across the larger end. Pour dirty water on top of the sand. Collect the water as it drips through. What do you observe about the water compared to its original condition? How effective is the sand? What other materials might be used in place of sand? Try some.

(Activity 4) Put tap water into an aquarium and let it stand for several weeks without the filtration system being turned on. Observe the water and note any changes in color or smell. After several weeks, turn on the filtration system and observe the results.

(Activity 5) Moisten a piece of filter paper with water and place it in a funnel on a support stand. Dissolve 20g of aluminium chloride in 100ml of water in a beaker. Slowly add 10ml of dilute sodium hydroxide solution. Pour the solution through the filter paper. Observe the material left behind (aluminum hydroxide, an insoluble precipitate). This chemical and filtration system is another way to remove materials from a liquid which may damage equipment it passes through.

Extensions: Have the students find out about other substances which are used in aerospace which may have to be distilled or filtered to avoid potentially harmful residue, ie., fuel.



SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

Several short periods

TYPE OF ACTIVITY:

Teacher Demo or
Student Activity

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Sterile Environ-
ment
Decontamination

SKILLS:

Control of
Variables
Hypothesizing

RESOURCES:

BK - A.3
FM - 49,52

Objective: To understand the importance of a sterile environment in which to test for the presence of alien life forms.

Materials: Dry beans (soaked in water overnight); four 250ml containers; water; iodine 3%; alcohol 70%; lysol.

Procedure: Place beans in each bottle and cover them with water. Add 10 drops of the following to each bottle in turn:

- Bottle A - iodine
- Bottle B - alcohol
- Bottle C - lysol
- Bottle D - nothing

Stopper the bottles with cotton and allow them to stand in a warm place for two or three days. Examine the bottles periodically for cloudiness and odor. How does one account for any changes in color or odor in the bottles? What difference might using sterile bottles have made in this experiment? Would sterilization of the beans have made a difference? What would happen if different temperatures had been used? How many variables can you identify in this experiment? How many did you account for or control?

Now have the students consider the problems involved with testing for life forms in samples of soil from another planet or in the moon rocks. How easy is it to introduce contamination from the testing materials? Consider what kinds of problems were encountered in sterilizing an entire space vehicle before it was allowed to land on another planet. Why might this be so vital? What methods might you envision could be used to sterilize a spacecraft?



Adapted from educational materials available from
the NASA Teacher Resource Room, Kennedy Space Center

A PEANUT CALORIMETER

32

Objectives: To understand that the energy produced by food may be measured by determining the heat produced by combustion of that food; to relate that concept to the energy produced during metabolism; to relate the above to the amount of calories needed by an astronaut in a weightless environment.

Materials: Can; 250ml beaker; thermometer; graduated cylinder; centigram balance; wire screen; cork; needle; food (peanuts, pecans, sugar cubes, vegetable oil or hard cooked egg white).

Teacher Background Information: The energy produced by the metabolism of food is precisely the same as that produced by burning the food (metabolism and burning are both oxidation processes). The heat produced by this process is measured in calories or BTU's. In most scientific work, the preferred unit is the calorie. A calorie is the amount of heat needed to raise the temperature of 1ml (1g) of water 1 degree celcius. The calories we talk about when discussing food are actually kilocalories (the energy required to heat 1000ml of water 1 degree celcius).

For very precise work, food is placed in a device called a bomb and lowered into a tank of water. The food is mixed with an exact amount of an oxidizer and all of the food is burned. Every bit of heat is measured by gently stirring the water and recording the temperature change. In this activity, even though not a precise experiment, a careful student should be able to realize results within 10% or so of actual values.

Procedure: Prepare the calorimeter assembly as shown in the illustration. Punch the holes around the bottom of the can before the bottom is removed. The can will act as a chimney to concentrate the heat on the bottom of the beaker of water so it should be about the same diameter as the beaker. Place the needle into the cork and attach the food to be tested to the other end of the needle.

Measure the mass of the food to be tested on a centigram balance.

Measure the mass of the water. (It will be easier if the students try for amounts like 100g or 150g.)

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

2-60 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Expository and
Guided Discovery

CONCEPTS:

Calorie
Combustion
Heat Energy

SKILLS:

Construction
Experimentation
Interpreting Data

RESOURCES:

BK - A.5;C

Measure the temperature of the water. Ignite the food and quickly place the chimney over the food and the screen and beaker on top of the can. Continuously stir the water gently. As soon as the food has stopped burning, record the temperature of the water again. Keep recording the temperature until it stops climbing. It may continue to climb for a few moments after the food ceases to burn.

Compute the Kilocalories/Gram for the food burned.
$$KCal = \frac{(\text{change in temperature}) \times (\text{grams of water})}{(\text{grams of food}) \times (1000)}$$

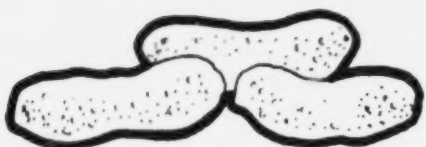
Try the experiment again or compare with others who used the same food. Several trials make for better accuracy. Try the experiment with other foods.

Discuss what some of the special considerations for caloric intake might be for an astronaut in space. Would the requirements be the same in the weightlessness of space compared to training back on Earth? Why or why not?

Try the "Run To The Moon" activity next. Keep your calculator handy!!

Helpful Hints: If you use vegetable fats during your test you may find them difficult to handle. You can make them easier to burn by soaking a little cotton or fiberglass with the oil first then igniting the cotton. Burn a measured amount of cotton first under some water and compute the caloric value of the cotton. Use the same amount of cotton soaked in fat or oil and subtract the first value for the cotton alone from your second results to compute the calories in the fat alone. A sugar cube will burn a little easier if you rub a few ashes on it first.

Extensions: For all practical purposes, all fats give off the same amount of calories and for all carbohydrates the caloric value is the same. In the experiments above, the vegetable oil would be a fat and the sugar cube would be a carbohydrate. The caloric value of protein can be found by subtracting the percentage values for fat and carbohydrate in a food from the total. What is left is the value for protein. Have the students compute the average values for fat and carbohydrates from their data and then compute the values for protein using the following chart.



PEANUT CALORIMETER CHART

<u>FOOD</u>	<u>KCal/g</u>	<u>%H₂O</u>	<u>% Protein</u>	<u>% Fat</u>	<u>%Carbohydrate</u>
Almond	6.4	4.7	18.6	54.1	19.6
Navy Bean	3.5	10.5	22.0	1.5	62.1
Bread, white	2.61	35.9	8.5	2.0	52.3
Cheese, cheddar	3.93	39.0	23.9	32.3	1.7
Cooking oil, Crisco	9.00	--	--	100.0	--
Egg, white boiled	.57	--	12.3	.6	--
Lard	9.30	--	--	100.0	--
Peanuts, roasted	6.00	2.6	26.9	44.2	23.6
Popcorn, popped	4.03	5.0	10.7	5.0	78.7
Pecans	7.47	3.0	9.4	73.0	13.0
Soybeans, dry	3.51	7.5	34.9	18.1	12.0
Sugar, white	3.98	0.5	--	--	99.5
Walnuts, black	6.57	6.0	27.6	56.3	10.0
Walnuts, English	7.02	3.3	15.0	64.4	15.6
Zweiback bread	4.22	6.0	9.8	9.9	73.5

Teacher Note: The values for Fats, Protein and Carbohydrate follow. You may wish to cut this off before reproducing this for you students if you want them to do their own computations.

Fats 9

Protein 4

Carbohydrate 4

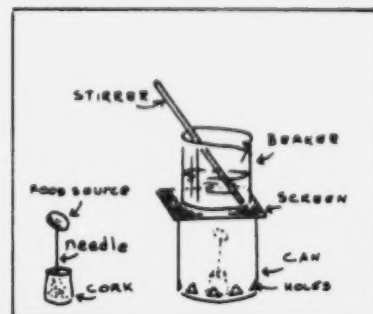


Illustration for making calorimeter

A RUN TO THE MOON

Objective: To provide students with an opportunity to determine how long it would take them to run to the moon and to relate that time to the energy requirements for a human and for a spacecraft making the same trip.

Materials: Stopwatch; meter tape; activity sheet provided; (optional - a loaf of white bread).

Teacher Background Information: The following activity is included to provide students with an opportunity to use some large numbers in determining how long it would take them to run to the Moon. In addition, information related to the energy requirements is furnished so that students can get some idea how much energy would be required for them to make such a voyage. Following the first part of the lesson, the students are asked to relate their own speed with that of a Saturn Rocket and to compute the energy requirements of the rocket for the same voyage.

Procedure: Hand out the activity sheet and ask that the students read the top and do Step 1 together with you. Together, set up an area outside which is 50 meters long and do Step II. After each student has recorded their time across the 50 meter run, have them use the graph on their activity sheet to compute the number of days it would take to run to the Moon.

Now, do part 2 of the activity sheet together. Do an example on the board so that everyone knows how to calculate the first question. Have them compute how many hamburgers it would take to fuel them for the run. Talk over the next two questions with them and ask them to determine what additional information they may need to answer.

The following day, have them compute the answers to questions 1 and 2 in Step IV using the data they have collected over night. First, determine the number of slices of bread in the loaf of sandwich bread you have brought to class. (The students may have been asked to find this out overnight.) Second, determine the weight of each slice by dividing the number of slices into the weight of the loaf. Third, Multiply the weight of each

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large Group

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Calorie
Energy/Mass
Time and Distance

SKILLS:

Reading and Interpreting Data
Interpolating Data
Using a Stopwatch

RESOURCES:

BK - A.1,5a,b
FM - 65,66

slice by the number of slices it would take to run to the moon. Fourth, divide this weight by 1000 to yield how many kilograms of bread it would take. Fifth, dividing the student's weight (mass) into the total weight of the bread in their "get to the Moon loaf" will yield the number of kilograms of bread to get one kilogram of kid to the moon.

Now, carry the exercise one step further. Explain to the students that our largest launch vehicle, Saturn V, can lift about 45,000 kg into orbit. This is the vehicle that took us to the Moon. It is 111 meters tall and when fueled has a mass of about 3,000,000 kg. The fuel alone has a mass of 2,700,705 kilograms. Dividing the payload of 45,000 kg into the total propellant mass yields a ratio of about 60 kg of fuel to lift 1 kg of payload into orbit. How does this compare with the students calculations on the kilograms of bread to lift one kilogram of student into orbit?

Extension: Have the students calculate their travel time and energy requirements to other planets in the solar system. See the activity, "How Long 'Till We Get There?" Discuss limiting factors on the speed of spacecraft. What might be some things that would slow a space vehicle down?

What might be some alternative energy forms to be used in space? Huge sails pushed by light have been suggested. What might other sources be? What might be the consequences of the use of nuclear fuel?



Activity sheet for

"A RUN TO THE MOON"

This activity will give you the chance to determine how long it would take you to run to the Moon. In addition, you will determine how much energy it would take you to make the run. Have fun!!!

Step I: Estimate how many days you think it would take you to run to the Moon if the average distance to the Moon is 386,000 kilometers. _____ days.

Step II: Determine the time it takes you to run 50 meters. Measure the time with a stop watch and record the time. _____ seconds.

Step III: Use the chart provided to determine how many days it would take you to run the distance to the Moon. _____ days.

Time to run 50 meters			Time to reach the Moon		
seconds	m/sec	days	seconds	m/sec	days
6	8.33	536	31	1.61	2770
7	7.14	626	32	1.56	2859
8	6.25	715	33	1.52	2949
9	5.36	804	34	1.47	3038
10	5.00	894	35	1.42	3127
11	4.55	982	36	1.39	3217
12	4.17	1071	37	1.35	3306
13	3.85	1160	38	1.32	3395
14	3.57	1251	39	1.28	3484
15	3.33	1342	40	1.25	3574
16	3.13	1427	41	1.22	3663
17	2.94	1520	42	1.19	3753
18	2.78	1607	43	1.16	3842
19	2.63	1699	44	1.14	3932
20	2.50	1787	45	1.11	4021
21	2.38	1877	46	1.09	4110
22	2.27	1968	47	1.06	4200
23	2.17	2059	48	1.04	4289
24	2.08	2148	49	1.02	4378
25	2.00	2234	50	1.00	4468



Activity sheet for "A Run To The Moon"(continued)

Energy requirements for a long run to the moon:

A calorie, remember, is defined as the amount of energy required to heat one gram of water one degree celcius. Remember also, that the food Calorie is really a kilocalorie (1000 calories, denoted with a capital "C"). The Calorie content of food is an important value to know since different foods provide different amounts of Calories and therefore, provide different amounts of energy to the user for different tasks. If an individual takes in more Calories than needed the excess is stored as fat.

A slice of bread contains about eighty Calories. Knowing this value, it is possible to determine the number of Calories and also the number of slices of bread it would take to fuel you for your run to the Moon.

As an example, it took a person running 50 meters every 15 seconds, 1342 days to travel the distance to the Moon. Multiply the days by 24 hours to get the number of hours to the Moon. If the average person burns about 864 Calories per hour while jogging, you can determine the Calories needed to run to the Moon by multiplying 864 times the number of hours to the Moon.

$$1342 \times 24 \text{ hours/day} \times 864 \text{ Calories/hour} = 27,827,712 \text{ Calories to the Moon}$$

Divide the total number of Calories by 80 (Calories in a slice of bread) to get the number of slices of bread you would have to take with you to eat along the way. $\frac{27,827,712 \text{ Calories}}{80 \text{ Calories/slice}} = 347,846 \text{ slices}$

Question 1.

How many slices of bread must you eat to make it to the Moon?

Question 2.

How high would a loaf of bread with this many slices be? _____
(clue: if a slice were 1.5cm thick, the loaf in the example above would be 1.5cm x 347,846 = 434,808cm high. About 4.3 kilometers - 2.7 miles high)

Question: If a double cheeseburger with lettuce, pickles, sauce, and tomato has 500 Calories, how many burgers would it take you to get to the Moon? ____

Question : If you stacked those burgers up, how high would the stack be?

How much would all this cost? _____

Next time some one wants to send you to the Moon, tell them it's going to cost a "lot of bread" baby!!!

Objectives: To understand how air pressure affects the boiling temperature of water; to relate this concept to the boiling point of blood and the need for a pressurized environment for humans in space.

Materials: Pyrex flask; stopper for flask; ring stand; heat source; glass or sponge; cold water; hot pads; pan to catch water.

Procedure: Fill flask with water $\frac{1}{3}$ to $\frac{1}{2}$ full. Bring the water to a brisk boil for at least 10-15 seconds. Turn off the heat source. Stopper the flask tightly (the water should stop boiling). **USE HOT PADS** to invert the flask on the ring stand. Pour cold water from the glass over the flask after placing a pan under the apparatus to catch the runoff. The water should begin to boil again. What may have caused the water to boil again? Does water always boil at the same temperature? Read the instructions on a cake mix box for high altitude baking. Why do you suppose it is necessary to cook for longer periods of time at high altitude? Could water boil at room temperature? How can you make a liquid boil without raising the temperature?

Safety Note: Do not use ice water. Cold water from the tap should work fine. Extremely cold water can cause such a pressure difference that the flask can implode. Do this as a demonstration and wear goggles.

Teacher Note: As the cold water is poured over the flask the steam inside will be cooled and will condense causing a lower pressure inside the flask. The lower the pressure the lower the boiling point of liquids. Relate the concepts learned in this lesson to the temperature of blood and the need for pressure suits or a pressurized cabin in a space craft. Pilots of aircraft which fly at high altitudes have used pressure suits for years. The "G" suits which some pilots use are to keep the blood in the upper part of the body (especially the brain) during high G maneuvers which might drain too much blood to the extremities (away from the brain) and thus cause a blackout. A space suit does not work in this way. It provides a pressurized atmosphere for the astronaut.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

45 minutes

TYPE OF ACTIVITY:

Teacher Demonstration

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Pressurized Environment
Boiling and Altitude

SKILLS:

Observation
Inference
Hypothesizing

RESOURCES:

BK - A.1,5;C
FM - 59,61,65

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large in pairs

TIME:

30 to 45 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Expository
and DiscoveryCONCEPTS:ESP
Telepathy
"Fair" ExperimentsSKILLS:Identification and
Control of
VariablesRESOURCES:

BK - A.5;H

Objectives: To duplicate ESP experiments tried by some of the astronauts; to develop methods of experimental data collection and experimental control.

Materials: ESP cards from study sheet; data recording sheet for each student.

Teacher Background Information: An experiment which took place on one space flight dealt with ESP and Telepathy. An astronaut tried to "send" thoughts to a person on the ground and visa versa. Quite a bit of scientific work is going on now in both the United States and Russia to test whether or not persons do have some ability to send information by thought wave alone. The following activity uses the same ESP cards the astronauts used in their experiment.

Procedure: 1. Run off the cards from the activity sheet on card stock or heavy paper if possible. You will need 5 each of the 5 designs.

2. Have students make a data sheet. (See illustration)

3. Have the students consider how to set up a "fair" experiment. What variables need to be controlled? How should the data be recorded? How will a record of the actual cards turned be recorded? How should the data be evaluated? What is the probability of a correct response by chance? How many correct responses indicate ESP sensitivity?

4. Suggested format...Have two students take a set of twenty five cards out of sight of the other students. Have one student turn the cards over one at a time and think of the card turned. Have the second student record on a response sheet what the card was and say "first card, second card," etc. until all twenty five have been turned. Have the students record the number of the card under the symbol on their sheet. (see the sample).

5. Have the students circle their correct responses as a student reads from the master list.

6. Repeat the experiment at least one more time and

preferably twice.

7. Evaluate the data. If there are students who consistently get more than 9 or 10 correct responses try to test them separately. Some researchers say that about one in five persons has ESP powers. How does your class data stack up against this?

Extensions: Research the findings of the astronauts. Try additional experiments in ESP including:

A. Clairvoyance, B. Precognition, C. Psychokinesis.

+		○	□	☆

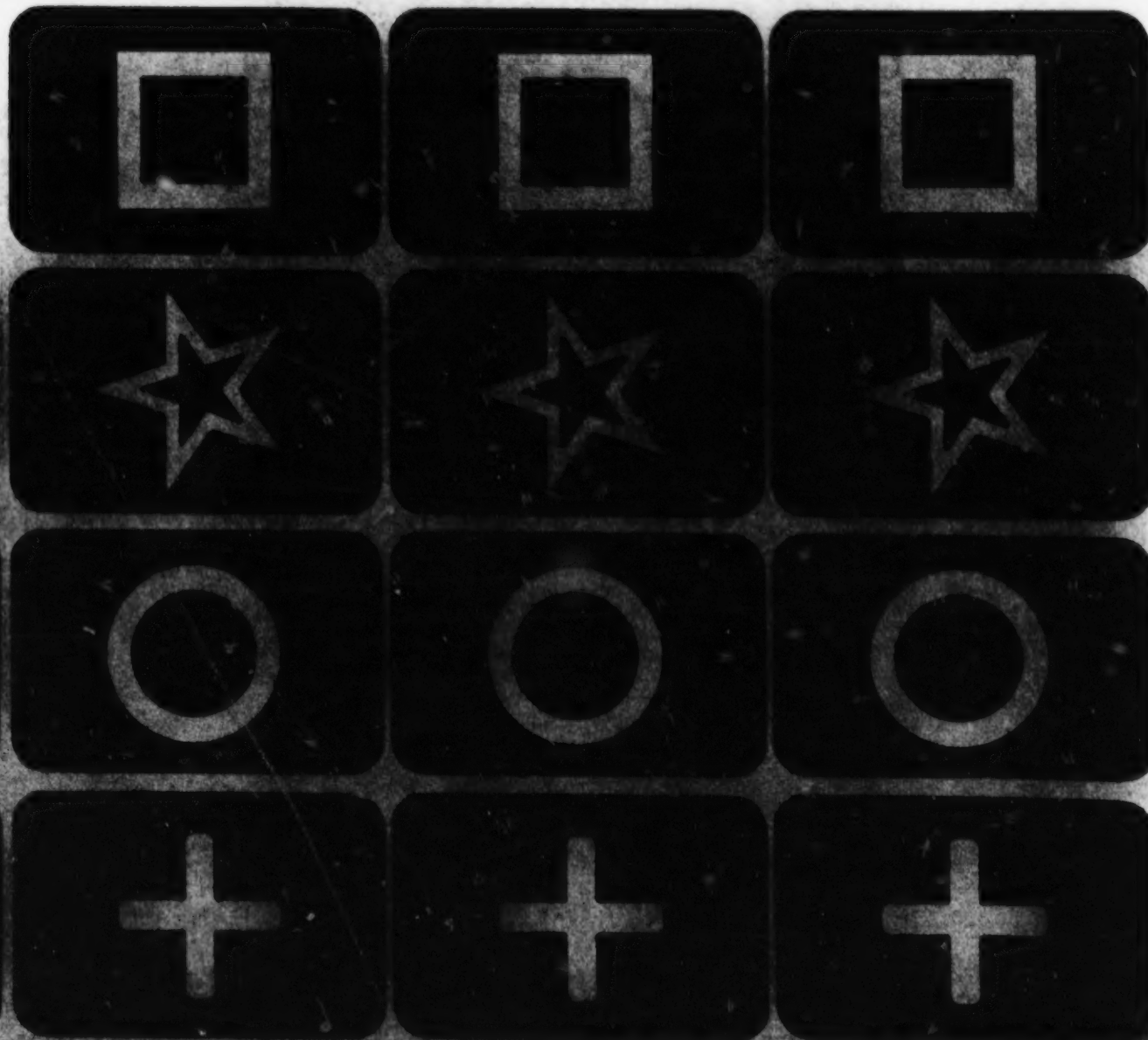
Illustration of Data Sheet

ESP Cards courtesy of Abruscato & Hassard, THE WHOLE
COSMOS CATALOG OF SCIENCE ACTIVITIES

PRINT TWO COPIES OF THIS
SHEET FOR EACH DECK NEEDED.

MOUNT THE SHEETS ON TAGBOARD

CUT OUT 5 EACH OF THE FIVE
DESIGNS TO PRODUCE A DECK
OF TWENTY-FIVE ESP CARDS.



Objectives: To help students understand how aircraft have impacted on the environment with positive results and with problems that need to be considered.

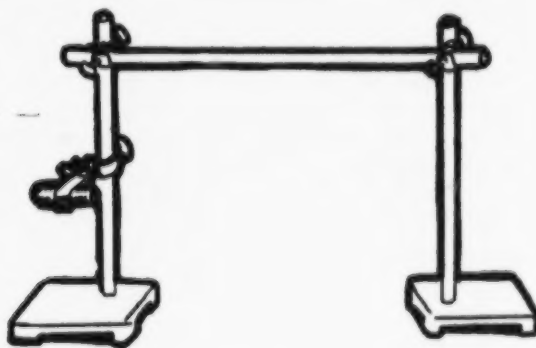
Materials: Books, pamphlets, encyclopedias on aircraft and what they do ("Aircraft and the Environment," Dept. of Transportation, FAA, Washington, D.C. 20591, is helpful); model rocket; $\frac{1}{4}$ A engine; 2 ring stands; ring stand test tube clamp; ring stand upright; 2 clamps or wire; model rocket ignition system.

Teacher Background Information: Set up the ring stand "launcher" as follows:

Attach the extra ringstand upright between the two stands with clamps (or wire the rod to the stands).

Attach the test tube clamp to the rear ring stand.

Insert the rocket engine in the clamp with the nozzle pointing away from the stand. BE SURE THE NOZZLE IS POINTED AWAY FROM FLAMMABLE MATERIAL AND AT LEAST 15 FEET FROM ANY WALL. If a vented hood is available, aim the rocket exhaust into the hood. If you do not do this experiment outdoors, ventilate the room right after the rocket is fired. Remember, the rocket discharges forward also.



Procedure: Ask the students to observe very carefully all that happens during and after the rocket "launches." Set off the rocket and ask them to relate what happened. "It went forward," will surely be followed by "It was loud" and "It smells!" Focus on the pollutants it leaves: noise, smell, smoke, etc. Think through with the students what sorts of environmental ramifications there may be as we send shuttle crafts up every 10 days or so.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

45 minutes

TYPE OF ACTIVITY:

Teacher Demo

Student Research

TEACHING STRATEGY:

Guided Discovery

Open Discovery

CONCEPTS:

Environmental

Impact

Pollution

SKILLS:

Observation

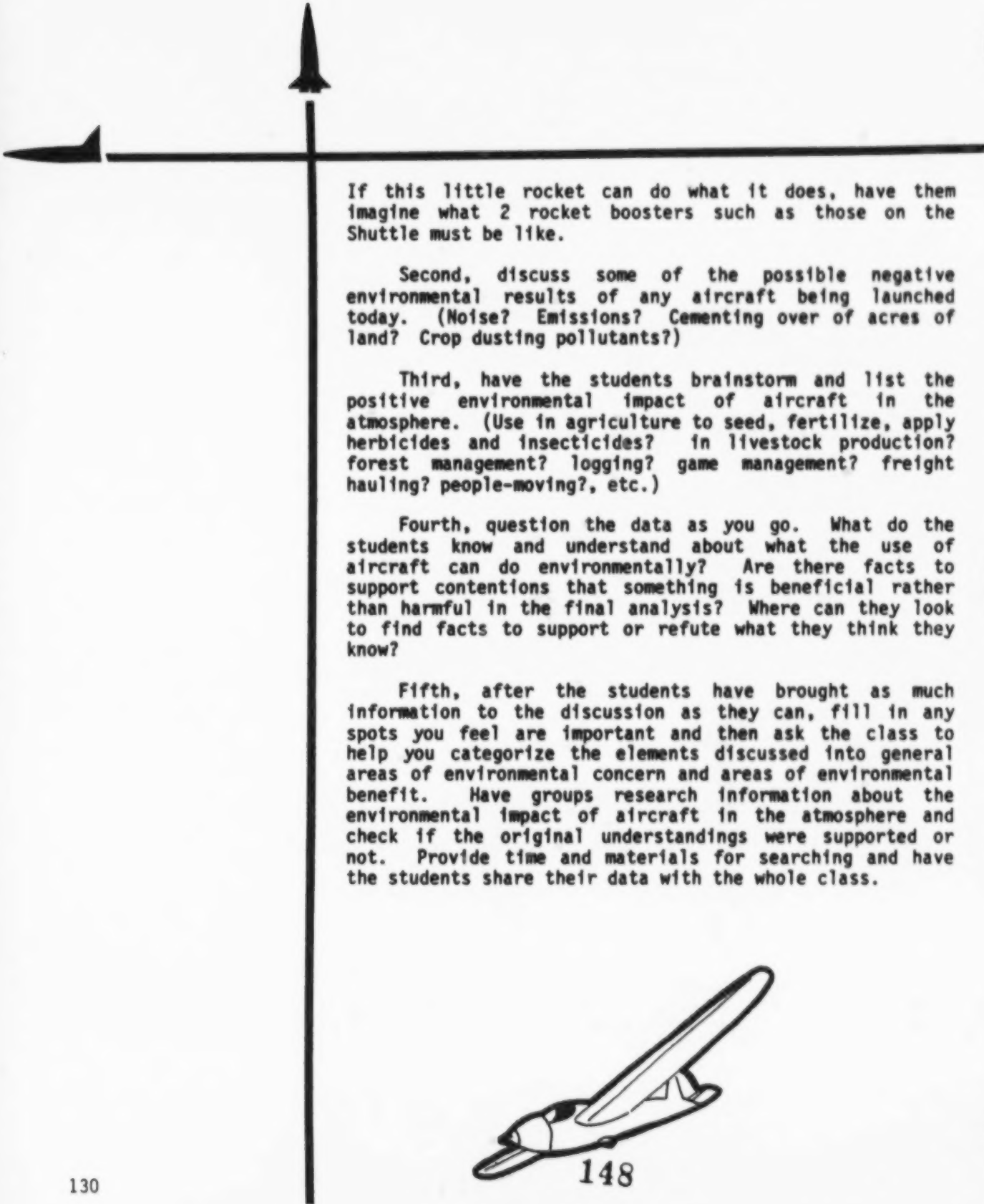
Inference

Research

RESOURCES:

BK - A.1;B

FM - 6,34



If this little rocket can do what it does, have them imagine what 2 rocket boosters such as those on the Shuttle must be like.

Second, discuss some of the possible negative environmental results of any aircraft being launched today. (Noise? Emissions? Cementing over of acres of land? Crop dusting pollutants?)

Third, have the students brainstorm and list the positive environmental impact of aircraft in the atmosphere. (Use in agriculture to seed, fertilize, apply herbicides and insecticides? in livestock production? forest management? logging? game management? freight hauling? people-moving?, etc.)

Fourth, question the data as you go. What do the students know and understand about what the use of aircraft can do environmentally? Are there facts to support contentions that something is beneficial rather than harmful in the final analysis? Where can they look to find facts to support or refute what they think they know?

Fifth, after the students have brought as much information to the discussion as they can, fill in any spots you feel are important and then ask the class to help you categorize the elements discussed into general areas of environmental concern and areas of environmental benefit. Have groups research information about the environmental impact of aircraft in the atmosphere and check if the original understandings were supported or not. Provide time and materials for searching and have the students share their data with the whole class.



Objective: to help students understand the "Spinoff" benefits of the space program for those of us on Earth.

Materials: Various books and/or pamphlets on "spin offs" from the space program. (NASA Spin Off books have been available each year for several years and are super sources.)

Procedure: 1. Ask your students to think of the things we now have because of the space program. Write the responses on the board and have someone keep a written record of them. (Most of the initial responses will quite likely be about the Space Shuttle, missiles or rockets, etc., and there will surely be a number of benefits the class will be unaware of.

2. When they have finished, explain that there are numerous benefits from the exploration of space and they can be broken into some basic categories:

- a. Communication Satellites
- b. Weather Satellites
- c. Landsat
- d. Oceanic Observers
- e. Defense
- f. Medical
- g. Other Technological Benefits (like freeze-dried food, alternative energy sources, computers, fabrics, metal processing, etc.)

3. Break the class into seven groups and have them research the benefits of space with a focus on their specific area of concern.

4. Have the students spend some time searching for information and collecting their data. Encourage students to write to NASA for information on the benefits of the space program. Michigan students can write to: Lewis Research Center, Teacher Information Center, Mail Stop 8-1, 21000 Brookpark Rd., Cleveland, OH 44135 or

Aviation and Space Center, Oakland University,
Rochester, MI 48063.

5. After gathering their data, have the students compile the information in a booklet with illustrations of some of the benefits they have found.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
small

TIME:
Several Days

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Open Discovery
Guided Discovery

CONCEPTS:
Spinoff
Technology
Research Benefits

SKILLS:
Research
Hypothesizing
Inference

RESOURCES:
BK - A.1;B.2;C;G;H
FM - 5,64

6. Bring the class together for a discussion and sharing of the booklets. Prior to class, write the original list of benefits the students had thought of on the board and then have each group present their booklet to the rest of the group. As benefits are presented, have someone write on the board those that were not brought up in the original discussion and compare the two lists.

benefits

space



Improved pacemaker, top hand, has its power cell recharged by external unit, bottom.

Test hospital room for paralyzed or severely disabled patients.

150

Vision Tester saves time.

Objectives: To provide an approximation of what it feels like in a weightless atmosphere; to relate earthbound activities to space activities.

Materials: Activity sheet (following lesson); graph paper; water bucket with water.

Teacher Background Information: The following activity is adapted from "Earthbound Astronauts" available as a pamphlet from ISS, University of Houston, Room 112 Farish Hall, Houston, TX 77004 (713) 749-1692. The pamphlet, along with another titled "The Physiology of Fear," uses amusement park activities such as those found at Cedar Point or Six Flags Over Texas, to do a lot of good teaching.

Procedure: 1. Before getting into a discussion of weightlessness in space, ask your students to imagine taking a bucket and filling it part way with water and swinging it over their heads. What will happen? Get the bucket and begin swinging the bucket back and forth. What happens to the water? Now, swing the bucket completely around over your head. What do the students observe about the water? Is it falling up into the bucket? Why? (anti-gravity)

2. Have the students imagine riding an elevator while standing on a bathroom scale. This is a thought experiment, so ask them to really get in touch with feelings they have experienced in elevators and then start them at the top floor. Ask them to imagine they are on the 20th floor standing on a scale. They push the button for the basement. What will happen to the reading on the scale? How long will this wonderful diet go on? What happens when the elevator slows down for its basement stop? (gain weight slightly) What happens when the elevator comes to a complete stop? (back to normal weight) Why does all of this happen?

3. If they are having trouble figuring it out, have them imagine jumping off a diving board while sitting on the scale. What would the scale read as they fly through the air? What can this be compared to?

4. Discuss some of the times when a person could feel what it's like to be "weightless." Free-

SUBJECT:

Science

GRADE:

7,8,9

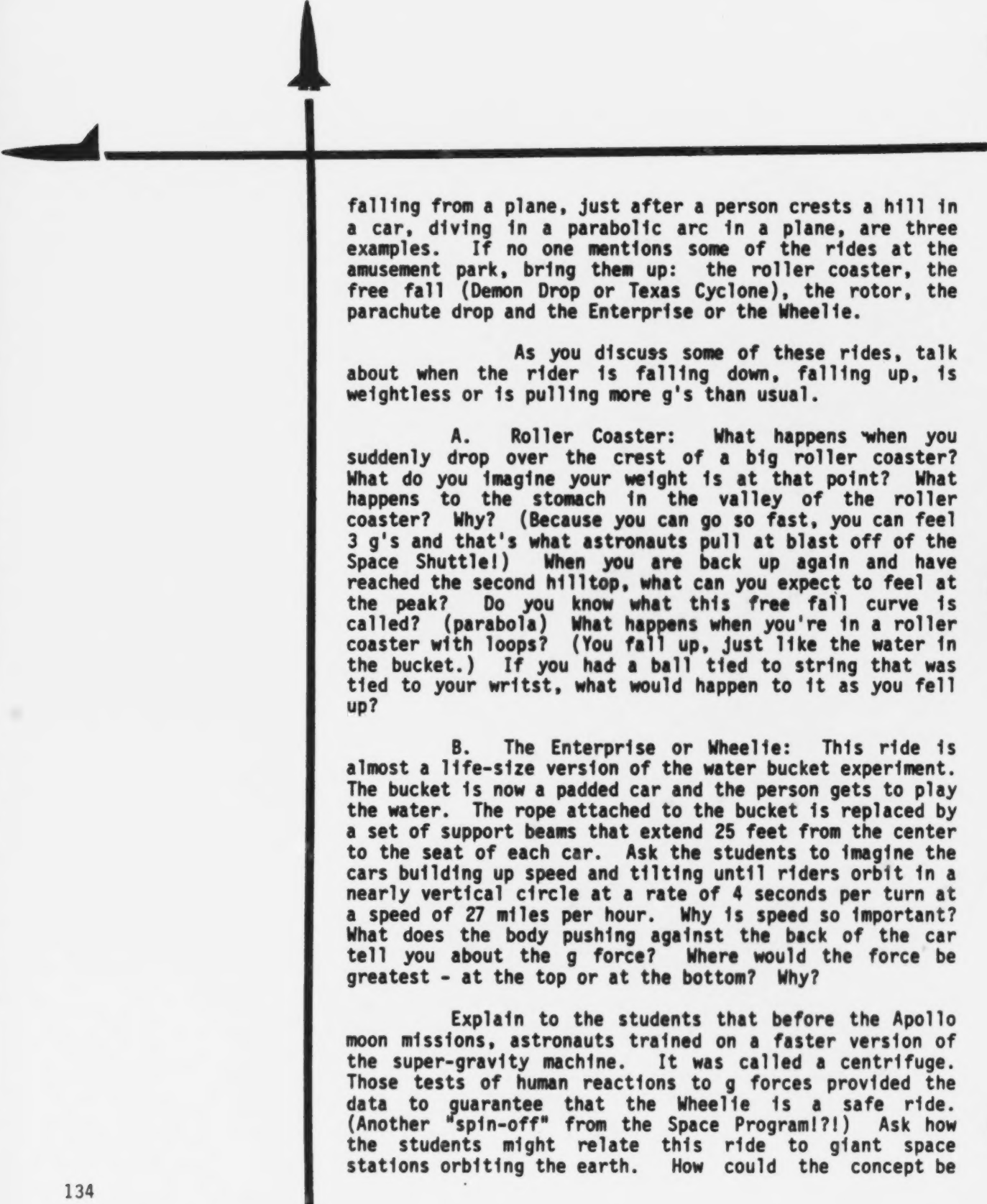
GROUP SIZE:

Large

TIME:

60 minutes

TYPE OF ACTIVITY:Discussion and
Student Investigation**TEACHING STRATEGY:**Guided Discovery
Expository**CONCEPTS:**g Forces
Gravity
Weightless**SKILLS:**Hypothesizing
Inference
Collecting Data**RESOURCES:**BK - A.1,5;I
FM - 48



falling from a plane, just after a person crests a hill in a car, diving in a parabolic arc in a plane, are three examples. If no one mentions some of the rides at the amusement park, bring them up: the roller coaster, the free fall (Demon Drop or Texas Cyclone), the rotor, the parachute drop and the Enterprise or the Wheelie.

As you discuss some of these rides, talk about when the rider is falling down, falling up, is weightless or is pulling more g's than usual.

A. Roller Coaster: What happens when you suddenly drop over the crest of a big roller coaster? What do you imagine your weight is at that point? What happens to the stomach in the valley of the roller coaster? Why? (Because you can go so fast, you can feel 3 g's and that's what astronauts pull at blast off of the Space Shuttle!) When you are back up again and have reached the second hilltop, what can you expect to feel at the peak? Do you know what this free fall curve is called? (parabola) What happens when you're in a roller coaster with loops? (You fall up, just like the water in the bucket.) If you had a ball tied to string that was tied to your wrist, what would happen to it as you fell up?

B. The Enterprise or Wheelie: This ride is almost a life-size version of the water bucket experiment. The bucket is now a padded car and the person gets to play the water. The rope attached to the bucket is replaced by a set of support beams that extend 25 feet from the center to the seat of each car. Ask the students to imagine the cars building up speed and tilting until riders orbit in a nearly vertical circle at a rate of 4 seconds per turn at a speed of 27 miles per hour. Why is speed so important? What does the body pushing against the back of the car tell you about the g force? Where would the force be greatest - at the top or at the bottom? Why?

Explain to the students that before the Apollo moon missions, astronauts trained on a faster version of the super-gravity machine. It was called a centrifuge. Those tests of human reactions to g forces provided the data to guarantee that the Wheelie is a safe ride. (Another "spin-off" from the Space Program!?) Ask how the students might relate this ride to giant space stations orbiting the earth. How could the concept be

used that way? Where on this spinning station, would it be most comfortable for people to walk about?

C. The Rotor: This is a turning barrel with a floor that drops down about a foot once the 12.5 foot barrel is spinning at full speed. Why do they have to wait until it has speeded up? It turns at about 35 turns per minute - about the rate of a long playing record - and produces a g force of over 2.5. Why are 2.5 g's necessary to this ride? What happens when the floor drops away? Why don't all the people fall down? How could this concept be used for space vehicles orbiting in space?

5. Hand out the activity sheet and talk about the Demon Drop or Texas Cliffhanger free fall ride. Where does weightlessness occur? Where would they feel the largest number of g forces? Make sure your students understand the way the ride works so the data recorded will make sense to them.

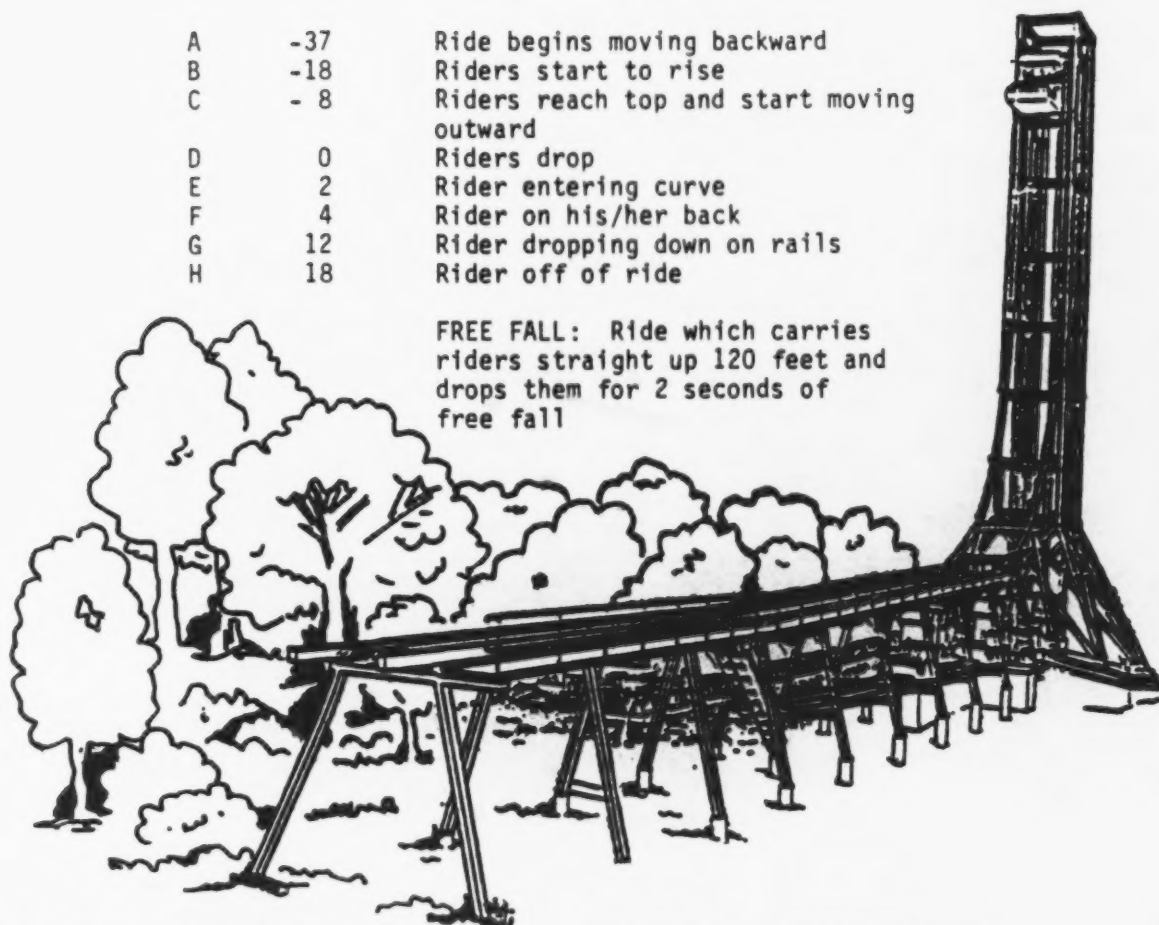
There are two parts to the activity. (a) Have the students use the first page of the activity sheets to do a graph of the two persons' pulse rates; and (b) have the students complete the answers on the second page of the activity sheets. Discuss with them, the physiological and the psychological ramifications of rides such as these. How do those ramifications relate to astronauts in space or, indeed, to any of us who might someday live and work in space?

Extension: Talk with the students about what other kinds of data one could collect at an amusement park and the ways the data could be recorded and then analysed. (Things like: What's the most popular ride? What's the average wait time on specific rides? What's the most common comment made by people as they come off a particular ride? How many people come to the park in an hour on average? What's the ratio of adults to children? etc., etc.) Talk about how important some of that information could be to the park owners and managers and how they use information like that. Make plans to visit an amusement park with your students, armed with specific questions you want answered and a scientific method to obtain those answers.

FREE FALL DATA SHEET

A	-37	Ride begins moving backward
B	-18	Riders start to rise
C	- 8	Riders reach top and start moving outward
D	0	Riders drop
E	2	Rider entering curve
F	4	Rider on his/her back
G	12	Rider dropping down on rails
H	18	Rider off of ride

FREE FALL: Ride which carries riders straight up 120 feet and drops them for 2 seconds of free fall



Pulse Rate - Joan Prukop

Pulse	Time	Pulse	Time
97	-25	131	19
97	-24	134	23
92	-23	135	25
95	-20	135	27
98	-18	132	28
92	-15	134	29
103	-14	131	31
130	- 7		
131	- 6		
124	- 5	Two data points from the audio-tape have been omitted due to electrode malfunction.	
130	- 3		
138	0		
136	4		
140	7		
147	8		
143	11		
144	12		
134	14		
132	15		
132	18		

Pulse Rate - Katie Jackson

Pulse	Time	Pulse	Time
95	-37	151	7
99	-32	144	9
103	-30	124	10
108	-28	138	11
103	-24	138	12
104	-22	137	13
104	-19	137	15
112	-17	132	16
101	-15	129	17
115	-13	124	19
132	-11	124	21
140	- 9	122	24
132	- 8	119	25
144	- 5	120	27
139	- 4	112	28
142	- 2	100	31
152	0	99	33
160	1	90	36
131	5	84	39
153	6	80	42

FREE FALL ACTIVITY

DATA ANALYSIS

Joan Prukop is a 30 year old physical science teacher riding the Texas Cliffhanger (Cedar Point calls it the Demon Drop) for the first time. Katie Jackson is a 13 year old student riding the Texas Cliffhanger for the second time (the first time on the recording day).

1. Where on the ride does Katie's pulse rate peak?

2. Where does Joan's pulse rate peak?

3. Offer a possible explanation for the difference.

4. Which rider's pulse rate drops back to normal more quickly?

5. In this ride, does the anticipation of the drop seem to cause pulse rates to rise?

6. What seems to be the effect on pulse rates of moving the riders slowly toward the drop? (points C-D)

7. What is the pulse gain for Joan? _____ (% gain: _____)

What is the pulse gain for Katie? _____ (% gain: _____)

8. What variables are there here that should be considered when comparing the two recordings? Can you make any generalizations from from these two pieces of data?

9. Which ride at an amusement park seems the most fear-inducing to you? Why do you think you feel as you do?

Objectives: To understand some of the problems the body faces while living in a weightless atmosphere; to apply the information in devising exercise equipment to offset the problems.

Materials: Books and pamphlets on the physical ramifications of living in space.

Procedures: 1. Talk with the students about what some of the problems of living in a weightless condition might be. Ask them to think about how their body functions in an atmosphere of 1 g.

- a. How hard is it to walk up hill?
- b. How much effort does it take to ride a bike?
- c. How are their muscles used to lift things?
- d. What sort of exercise do they get when they run?
- e. Are their legs, arms, lungs and heart all affected by exercise?
- f. How does gravity enter the picture here?
- g. What might happen to people who are unable to use their arms or legs for long periods of time, for example, when people have to stay in bed for several weeks?
- h. How vital is exercise to a well conditioned body?
- i. How important is gravity and the resistance it provides to a well- conditioned body?

2. Discuss what might happen, then, if people were to try to live for long periods without gravity. Have the students make some predictions based on the earlier discussion.

3. Have the students do some research on what space scientists have found out about the body's response to weightlessness. Spend some time gathering information and sharing it in class.

4. Finally, have the students devise, either on paper or with a model, a compact, useful piece of exercise equipment that will help solve at least one of the physiological problems caused by weightlessness. Remind them to think about such things as:

- atrophy of the muscles
- loss of muscle mass, especially in the legs

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
60 minutes

TYPE OF ACTIVITY:
Discussion and
Student Activity

TEACHING STRATEGY:
Guided Discovery
Expository

CONCEPTS:
Weightless
Atrophy
Conditioning

SKILLS:
Reading for Infor-
mation
Measuring

RESOURCES:
BK - A.1,5;C
FM - 18,48,65,66

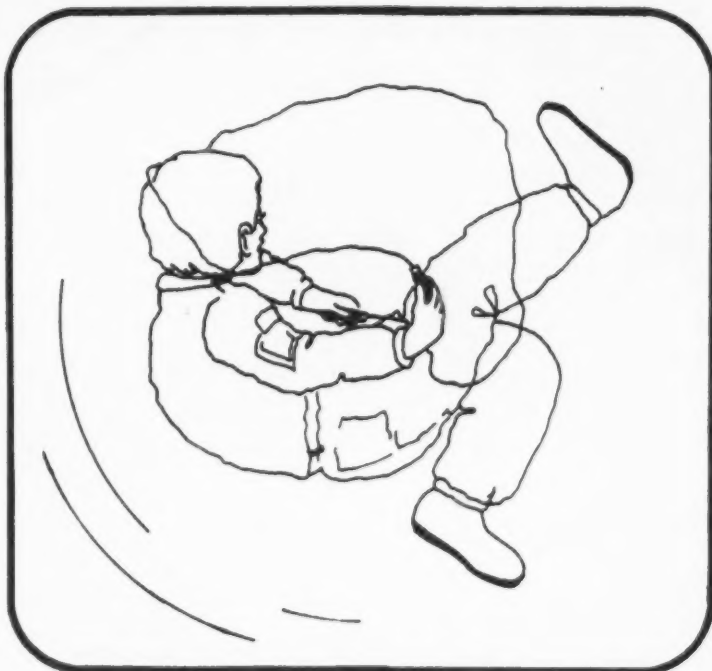
- loss of calcium and bone strength
- how to keep the person attached to the equipment
- how to provide resistance in micro-gravity conditions
- how to provide aerobic conditioning

WHILE THEY ARE AT IT...ask your students to keep a look out for answers to such questions as:

- Why are people taller in space?
- Why is the heart rate lower in space?
- Why does a person's face swell in space?

When the students are ready to share their exercise equipment models or drawings, see if anyone has also run across some answers to the "extra questions" and can share them with the class. Also, if anyone has thought of a question he or she would like answered, see if the class can think of ways to possibly find the necessary information.

Extension: Check the K - 6 COME FLY WITH ME materials for the following activities which relate to the body in space: #62-Pilot Test, #63-Human Reaction Time, #64-Lung Capacity, #90-Recording Heart Rate, #91- Physical Fitness in Space.



Objective: To give students the opportunity to understand some of the psychological needs of living in an enclosed environment in space.

Materials: Paper and pencils.

Procedures: 1. Have students break up into groups of six or seven. Try to see to it that the groups are as heterogeneous as possible.

2. Ask each group to spend ten minutes brainstorming the psychological needs of people living together in a closed environment. Ask them to imagine that the vehicle is occupied by the six or seven people in their group, that the space they occupy is approximately the size of an average classroom and they are to be in this space for twelve days. Each group should have someone jot down what the group comes up with.

3. After they have spent 10 minutes brainstorming, inform them that the reentry ability of the capsule has malfunctioned and that ground control has determined that they cannot return for a year when they estimate the engineers will have a rescue vehicle built capable of picking them up and returning them to earth. All other areas of concern are taken care of: food is plentiful, all systems for pressurizing and decontamination, for example, are fine. Now, what other psychological considerations are there to be concerned with since the trip will take a whole year? Have them brainstorm and keep notes.

4. Bring the groups together and share what each of them came up with. How did the two periods of time affect their lists of psychological concerns? Can they prioritize some of the concerns? How important are the psychological ramifications to a successful living arrangement in a closed environment in space?

5. Finally, have the students work together in their groups to design a craft that is expected to be in space for two years. Assume all physical considerations have been met, but the groups are to imagine they are psychologists who are responsible for determining the most appropriate and emotionally healthy way to provide for the psychological ramifications of

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
60 minutes

TYPE OF ACTIVITY:
Student Investigation

TEACHING STRATEGY:
Open Discovery
Guided Discovery

CONCEPTS:
Psychological
needs
Living in Space

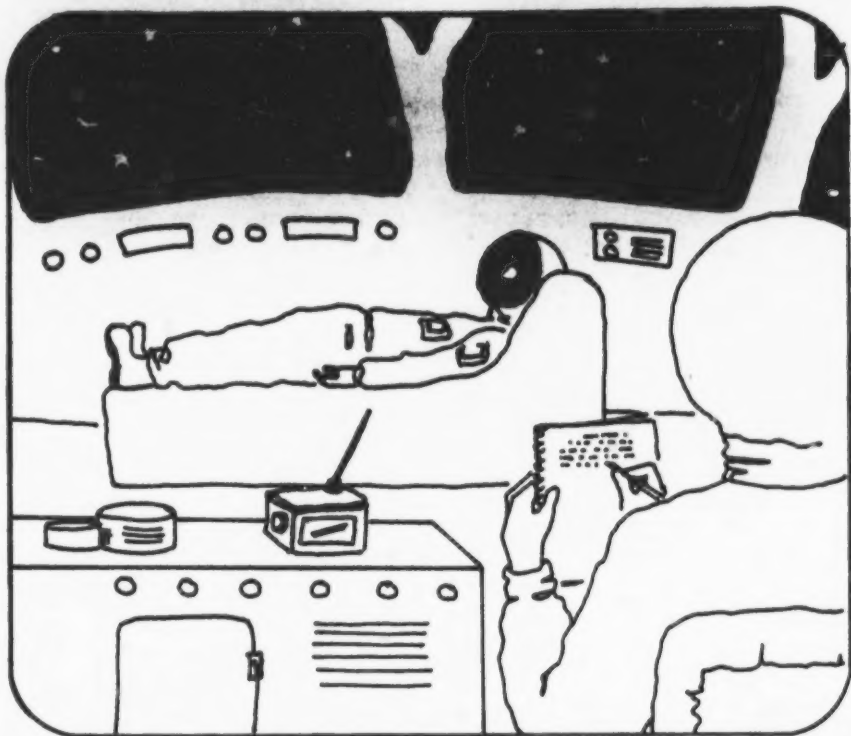
SKILLS:
Hypothesizing
Working in Groups
Inference

RESOURCES:
BK - A.5;C;H
FM - 65

living in space for two years. How would they provide for these in the design of the craft? Ask each group to share their craft and the ideas they come up with with the larger group. Drawings or models with explanations would be fun.

6. After the sharing, discuss whether there were differences in how each of the groups approached their task. Were there any differences in what was deemed as psychologically important to the members of the various groups? Were there differences in what members within groups felt was important? Is it helpful to have a meaningful cross-section of people with a variety of perceptions when groups engage in discussions of this sort? Have them check out how NASA approaches problem solving questions such as this.

Extensions: Have students research the 1973-74 Sky Lab space station orbits for information on how a crew of three spent 84 days in space.



Objectives: To demonstrate how to collect and grow living things in a nutrient medium; to relate the experiment to scientists searching for life in space.

Materials: Refrigerator jars, plastic butter tubs or covered petri dishes; bread.

Teacher Background Information: Molds, yeasts, or similar micro-organisms can be found almost anywhere in the world. Any bit of material, whether of air, water, or earth, contains numerous examples of such micro-organisms. Under ideal conditions, they sprout into lush, spectacularly beautiful, microscopic jungles.

This simple form of life offers space scientists a means of investigating the possibility of life on other planets. Scientists believe there is a greater possibility that this type of plant life, or something comparable, would be associated with other living things. Accordingly, they have designed small robot instruments which land on the surface of distant planets and draw some of the surrounding material inside and drop it into a culture medium. Periodically, this liquid food is checked for chemical changes and the container for temperature or atmospheric composition changes. This information is transmitted back to the earth where the biological scientists compare it with already existing knowledge.

Procedure: A covered refrigerator dish or clean glass jar makes a good environmental area for some types of microorganism growth.

1. Have students obtain a supply of molds by rubbing a piece of bread across a carpet or other floor area. Moisten the bread and put it into a covered environmental area for several days. (Since molds and related plants do not possess chlorophyll, they should flourish without sunlight.)

2. After several days, have the students examine the growth with a low powered microscope or hand lens. Viewing is best with a bright light falling on the surface of the growth. Ask students to notice the rate and types of growth as well as changes in the base materials.

3. Ask students to think of experiments scientists

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

small

TIME:

Several Days

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Guided Discovery
Discussion

CONCEPTS:

Nutrient Medium
Extraterrestrial
life

SKILLS:

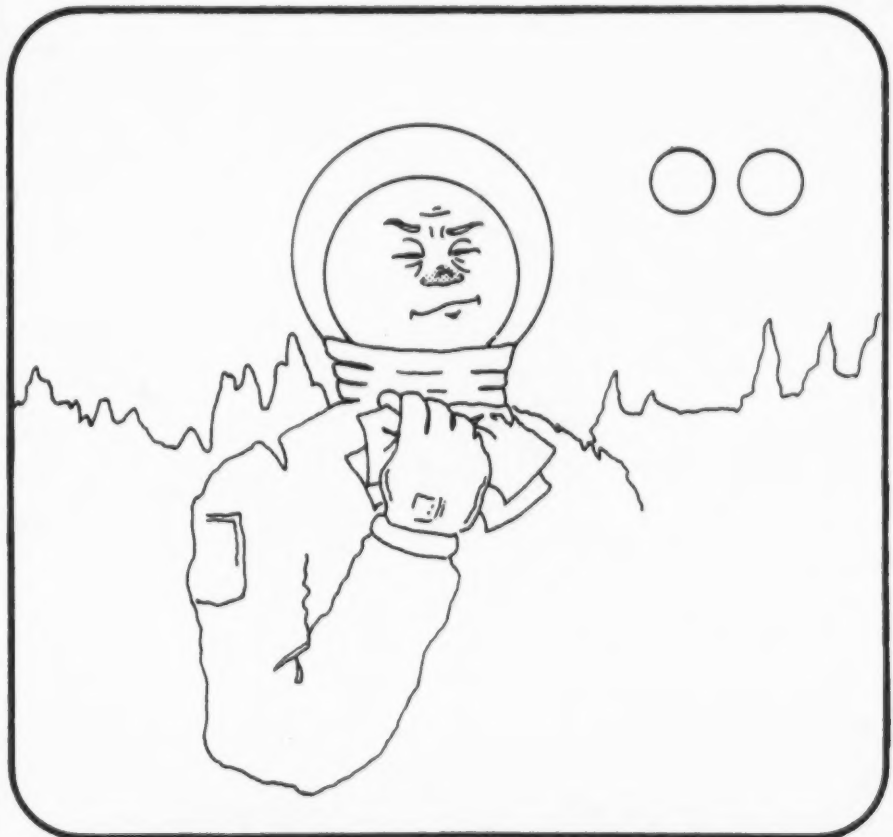
Experimentation
Interpreting Data
Hypothesizing

RESOURCES:

BK - A.3d;E
FM - 36,39

might do in order to determine if life exists on another planet. Why would it be important to determine this? Might there be a need for protection from some microbes in space? Discuss virulent and benign forms of microorganisms.

4. Ask the students what finding microorganisms in space might say about the likelihood of finding more complicated forms of life in space. Relate this experiment to the Voyager experiments and have the students do some research on how the scientists went about looking for life and what they found. Relate this activity to your general study of mycetes.



MOON ROOM FOR RENT - BEAUTIFUL VIEW

Objectives: To provide students with a greater understanding of the moon; to apply concepts of the moon to futurizing about what it would be like to live and work there.

Materials: Books, pamphlets, etc., about what we've learned about the moon.

Teacher Background Information: Just as Galileo's telescopic observations of the moon opened a new era in modern astronomy, Neil Armstrong and Edwin Aldrin's walk on the moon opened a new discipline in science - lunar science. Since it is quite likely that we and our students will see some sort of colonizing of the moon, it is important for our young people to know more about our nearest neighbor and potential home away from home.

In addition, it is important that students attempt to futurize - to use what they understand and know to be true now to try to predict what life might be in the future. Only with this ability will they have even a minimal chance of controlling their futures and we owe them, at least, that.

Procedure: 1. Discuss with the class some of the things they understand to be true about the moon (our nearest neighbor in space; accessible by Saturn rocket and lunar lander as well as other rockets; one sixth the gravity of earth; waterless, airless and lifeless; similar crust and about the same age as earth; pummelled by meteorites; cratered; sunlit on one side, for example). As questions arise, write them down and devise ways with the class to find answers.

2. Explain to the students they will need to know as much as they can about the moon in order to do some intelligent futurizing about a moon colony they could live on. Provide the students with the resource material you have and time to check further with the library or to write for information if materials are scarce.

3. Once the students have some information from which to work, break them up into groups of 3 or 4 and explain they will be constructing a "moon city" out of whatever materials they wish to use.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
Several periods

TYPE OF ACTIVITY:
Student Research
Constructing Models

TEACHING STRATEGY:
Open Discovery
Guided Discovery

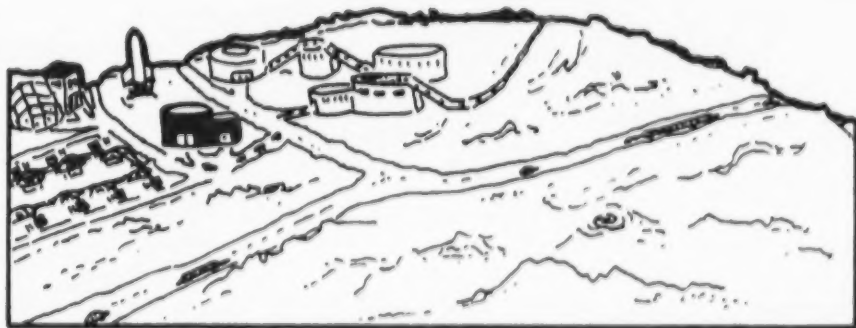
CONCEPTS:
Living on the Moon
Colonies
Human Needs

SKILLS:
Reading for Data
Futurizing
Construction

RESOURCES:
BK - A.5b;C;D.5c3
FM - 49,52,53,60

4. Explain to the students that this is a very integrated activity. They should know that they will be expected to use their skills in science, mathematics, architecture, sociology, psychology, political science and economics. They will be expected to consider health care, education and the question of who's in charge on this colony. It is expected that, though people can travel back and forth from the city to the earth (just as some raw materials and finished goods will) most of the people will live out their lives on the moon city and all contingencies for life must be accounted for.

The teacher's ability to encourage students to focus on what they know and what they need to find out before and during the construction is very important. It is very easy for students to fall into science fiction without reality based concepts and, though that can be fun, it does not help to meet the objectives of this lesson. Make certain the students know that evaluation will be based on what you have explained are your expectations about the project. In addition, they will be evaluated on how well they discuss their "city" and answer questions from the class about it.



Objective: To utilize understanding of the hostile environment of space in constructing a model space colony.

Materials: ANYTHING YOU CAN THINK OF! Styrofoam or paper plates, hamburger and pie containers; cardboard rolls; straws; styrofoam or paper cups; plastic soda bottles; flat cardboard, felt pens; string; toothpicks; glue; scissors; Exacto knives; masking tape; bits and pieces of colored paper; paint; styrofoam "peanuts" (they make great space people!).

Procedure: (A) Brainstorming.

1. Write "The Year 2084" on the chalkboard and circle it.

2. Ask students to share what kinds of things they think we would have to concern ourselves with if we were living in space in the year 2084. Jobs, food, entertainment, oxygen, gravity, schooling, plants, storage, enclosed environment, etc. are some of the things that will likely come up. As they share, discuss the problems that are involved with each. Search for solutions. Share ideas with each other.

3. Ask the class whether they really feel we will be able to live for long periods in space in the year 2084. Sooner? Later? What will a space colony look like? What might we have a space colony for? These can be pretty important questions and the students should be encouraged to use all the information they have gathered through their aerospace and other activities to think about them.

4. Ask the class to make some predictions about the future and discuss the difficulty of making predictions in such swiftly changing times. Talk about how it is more vital than ever to learn how to think rather than learning how to memorize out of date answers.

5. Explain that groups of students will be constructing their own space colony starting the following day and they should be thinking about what they would like that colony to look like. Show them what you have gathered in the way of materials and encourage them to bring whatever else they think they will need.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

Several periods

TYPE OF ACTIVITY:

Modeling
Student Research

TEACHING STRATEGY:

Open Discovery
Guided Discovery

CONCEPTS:

Colonization of
Space
Human Needs

SKILLS:

Hypothesizing
Futurizing
Construction

RESOURCES:

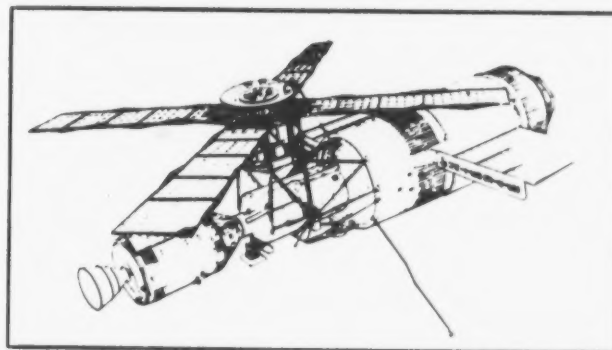
BK - A.2c;B;C;H
FM - 47,61,66

(B.) Construction.

1. Divide the class into groups of 4-5.
2. Explain that each group will construct a space colony where people live and work.
3. Explain that, at the end of the construction, the group will be responsible for explaining their construction, what the various parts of the colony are for, how concerns such as weightlessness, lack of oxygen, decontamination, energy, entertainment, learning, sleeping, loneliness, etc., are being met on the colony. In addition, they should be able to talk about the people living in the colony, who they are and what they do there.
4. As the students construct their colonies, allow adequate time for research and discussion. They should know that real involvement during the construction will be the best way for them to truly understand some of the ramifications of living in space.
5. As the students work, the teacher should also actively engage in the process: ask what is happening, what problems are being solved, what things are and encourage the groups to explore and answer questions they may not think of on their own. Reinforce the science concepts involved throughout the construction phase.

(C.) Presentation.

Ask each group to set up their display in an appropriate part of the room. The displays should be "self-explanatory" to some degree (much like a science fair project) but the groups will also be called on to make a verbal presentation. If possible, ask another class in to share the presentations.



THE SHUTTLE GOES TO THE FAIR

44

Objectives: To give students a greater understanding of what happens as people live and work aboard the Shuttle; to provide ideas for possible science fair projects.

Materials: "Space Shuttle Search Assignment Sheet," (following activity); Books, pamphlets, etc. on the Space Shuttle; Shuttle models or pictures.

Teacher Background Information: One of the concerns most science teachers have is getting students to do meaningful science projects either for class or for the annual science fair. One of the reasons for this seems to be that kids tend to do projects "in a vacuum;" they seldom see how what they've been studying relates to them or how it could be extended to an idea for a project. When they do understand how something can be bridged to their own lives, experiments or investigations become a great deal more inviting for most.

This activity is an example of how this can work. Small groups of students research Shuttle topics and have the opportunity to present their information to the class verbally and with visual effects. Following the presentation, the teacher and the class engage in a brainstorming session on each of the eleven topics, looking for related ideas that might lend themselves to a question which could be investigated for a science (fair) project.

Procedure: (Part I) 1. Show the students a model or pictures of the Space Shuttle. Ask what they already know about how the Shuttle works, what people do on it, how life is provided for. Because of press coverage, they should have some conceptual knowledge about the Shuttle; however, some of their information is likely to be incomplete and some may be incorrect. ENCOURAGE STUDENTS TO QUESTION RATHER THAN TO GIVE INFORMATION ABOUT CONCEPTS THAT ARE FUZZY.

2. When the discussion is completed, break the class into eleven groups and give each group ONE of the assignments from the sheet. Provide time and resources for the students to search for information on their topic. Explain they will be expected to compile their data and to present it on a specific day.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual or Small

TIME:

Several Weeks

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Open Discovery
Guided Discovery

CONCEPTS:

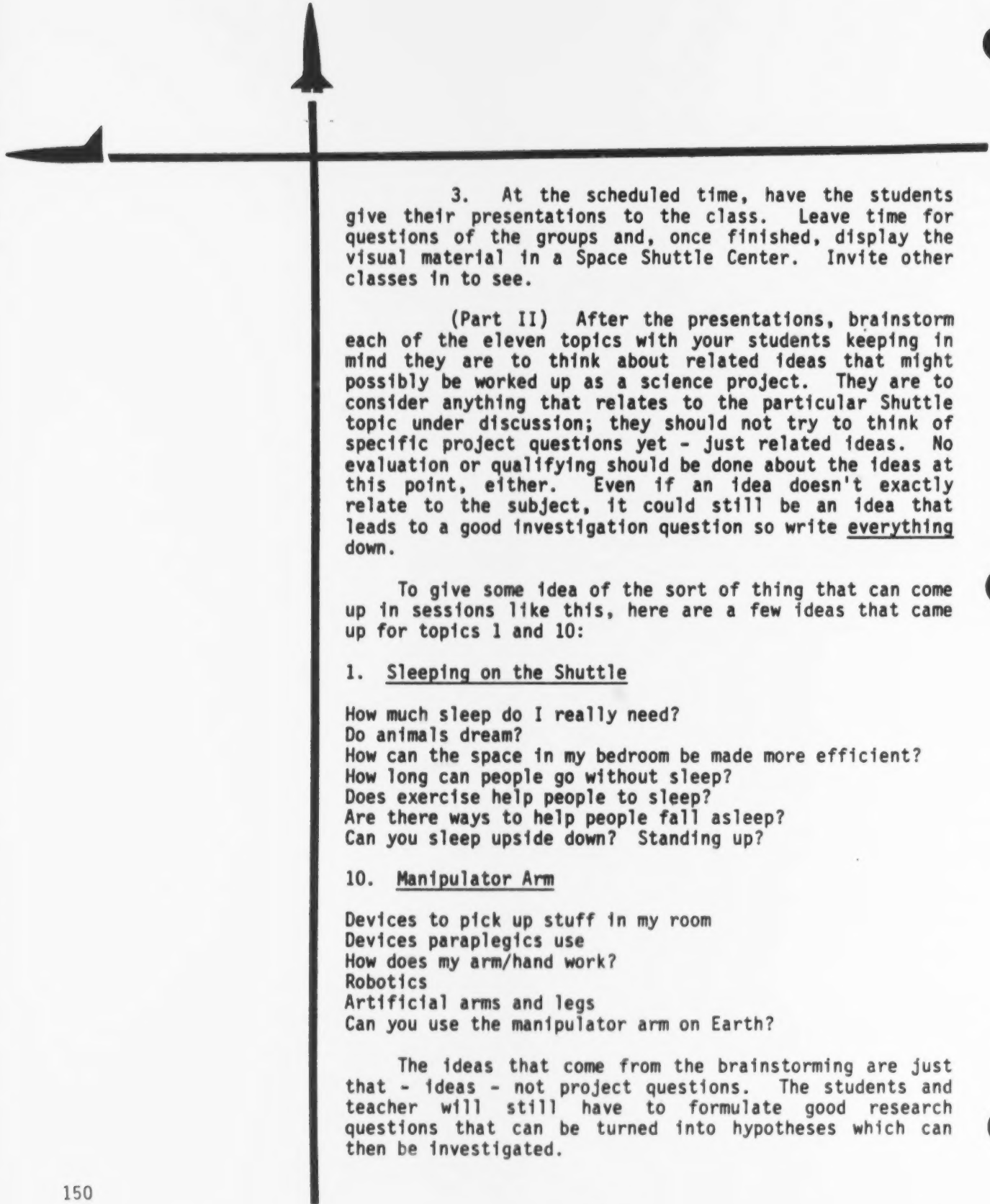
Research
Space Shuttle

SKILLS:

Experimentation
Collecting Data
Reporting Data

RESOURCES:

BK - A.1,5e;B;D.3a;H
FM - 63



3. At the scheduled time, have the students give their presentations to the class. Leave time for questions of the groups and, once finished, display the visual material in a Space Shuttle Center. Invite other classes in to see.

(Part II) After the presentations, brainstorm each of the eleven topics with your students keeping in mind they are to think about related ideas that might possibly be worked up as a science project. They are to consider anything that relates to the particular Shuttle topic under discussion; they should not try to think of specific project questions yet - just related ideas. No evaluation or qualifying should be done about the ideas at this point, either. Even if an idea doesn't exactly relate to the subject, it could still be an idea that leads to a good investigation question so write everything down.

To give some idea of the sort of thing that can come up in sessions like this, here are a few ideas that came up for topics 1 and 10:

1. Sleeping on the Shuttle

How much sleep do I really need?
Do animals dream?
How can the space in my bedroom be made more efficient?
How long can people go without sleep?
Does exercise help people to sleep?
Are there ways to help people fall asleep?
Can you sleep upside down? Standing up?

10. Manipulator Arm

Devices to pick up stuff in my room
Devices paraplegics use
How does my arm/hand work?
Robotics
Artificial arms and legs
Can you use the manipulator arm on Earth?

The ideas that come from the brainstorming are just that - ideas - not project questions. The students and teacher will still have to formulate good research questions that can be turned into hypotheses which can then be investigated.

SPACE SHUTTLE SEARCH ASSIGNMENT SHEET

1. Find out how the astronauts sleep on the Shuttle. Investigate the difference between some earlier sleeping arrangements (for example, what were the sleeping arrangements on Apollo II?) and the Shuttle's facilities. Explain to the class how things have changed. Use illustrations or models to show how the astronauts sleep. Explain what time they go to sleep and what time their work day starts.
2. Find out about the Shuttle Orbiter's food system. Find out what sort of food is eaten by the astronauts, how much, how it's prepared, stored, etc. Tell the class how the astronaut diet is figured out and where they can get similar food. Bring samples of the sort of food eaten on the Shuttle and share with the class.
3. Find out about the space suits and head gear worn on board the Shuttle. How do they differ from earlier models for other missions? What are they made of? Are they made for male and female crew members? (Find out only about the gear worn inside the craft as another group is working on the EVA gear.) After you have your information gathered, make drawings or find pictures to show the class what the gear looks like and how it works.
4. Find out how the Shuttle is launched. Using an illustration of the Shuttle, show the class the basic parts of the craft and explain how it gets off the ground and how it enters orbit. What kind of fuel is used? How many g's are experienced on take off? (What IS a "g"?) How is the g force better now with the Shuttle than most other manned flights? How fast does the Shuttle orbit? Describe to the class what can be seen as the Shuttle orbits the Earth. Bring pictures of take off. They're beautiful. Bring pictures of what the astronauts see while in orbit.
5. Find out about weightlessness on the Shuttle. (Did you know you'd be taller in space than on Earth? Find out why.) Explain to the class what happens in weightless conditions when you eat, go to the bathroom, take a shower or do work on board. How are the problems solved on the Shuttle? Bring pictures or drawings of astronauts in weightless conditions. Tell the class how NASA prepares astronauts to live in weightlessness.
6. Find out why it's so important for the astronauts to exercise in space. Find out what kind of exercises do the job and what some of the problems are. Show the class a drawing of the treadmill and explain its use. Why is it important that astronauts be in good condition before they come on board? Why do they need to exercise after they get there? Why are the needs greater the longer the flight?
7. Find out how the air manufacturing and control system inside the Shuttle works and why it's so VITAL up there where the Shuttle orbits. Why would your blood boil in space? Find out and tell the class how the Shuttle engineers keep that from happening to the astronauts. Explain how the air is purified. Bring something that illustrates to the class how the whole process works.
8. You won't be able to shower on the Shuttle, but you will be able to stay clean AND go to the bathroom when necessary. How come showering is such a problem and just how does one go about staying on the toilet seat in a weightless condition? Find out how NASA has provided for the personal hygiene of its astronauts. Find out why the fuel cells on board are so important to this provision. Explain why it's so VITAL that this aspect of space travel be carefully provided for and, while you're at it, find out why you don't have to trim your fingernails as often in space. Bring pictures or drawings of the personal hygiene facilities to show the class.
9. Find out how the astronauts, while in orbit, leave the Shuttle and why. Find out what kind of gear is used for EVA (Extra-Vehicular Activity). Find out and explain to the class the procedure used to leave the vehicle and some of the things the astronauts do outside the craft. Explain how gear protects the astronauts from the hostile environment. What would happen without it? Bring pictures or drawings of EVA to show the class.
10. Find out about the Manipulator Arm. How does it work? Why is it so helpful to the astronauts? What does it do in space? How is it like a human arm? Make a model for the class of the "space crane" showing the movable "shoulder", "elbow" and "wrist" on the "arm". Explain how it works. Bring pictures of the arm.
11. Find out how the Space Shuttle comes back to Earth. Find out when the astronauts begin re-entry procedures and explain to the class the steps they go through to bring the craft back to the landing site. Explain how a vehicle that took off as a rocket, comes back as an airplane. How fast is it flying as it touches down? What is its angle on re-entry? How does it differ from most other airplanes? What happens to the Shuttle after it returns? How is that different from other spacecraft in the past?

EARTH SCIENCE



CONTENTS

" ... to see ourselves as riders on the earth together,
brothers on that bright loneliness in the eternal cold."

Archibald MacLeish

EARTH SCIENCE OBJECTIVES

1. TO UNDERSTAND THE IMPORTANCE OF SATELLITES AND SPACE PROBES AS A MEANS OF OBTAINING INFORMATION ABOUT OUR ENVIRONMENT.
2. TO GAIN A BASIC KNOWLEDGE OF THE TECHNIQUES USED BY SCIENTISTS TO GATHER AND INTERPRET DATA FROM SATELLITES.
3. TO GAIN A BASIC UNDERSTANDING OF OUR SOLAR SYSTEM.
4. TO UNDERSTAND THAT CERTAIN ENVIRONMENTAL CONDITIONS IN SPACE MAKE IT NECESSARY TO INVESTIGATE WITH ROBOT PROBES RATHER THAN WITH HUMAN BEINGS.

LESSONS

- | | |
|--|--|
| 45. EXPLORING SOLAR CELLS | 57. WEATHER FRONTS MOVE |
| 46. LET IT SHINE | 58. READING AND PLOTTING WEATHER DATA. |
| 47. WARM ALL OVER | 59. ASTRONOMICAL UNITS |
| 48. WHERE ON THE WORLD ARE WE? | 60. PARALLAX ONE |
| 49. LONGITUDE AND LATITUDE | 61. PARALLAX TWO |
| 50. MAPPING A PLANET'S MAGNETIC FIELD | 62. RADIO TELESCOPES |
| 51. WEIGHTLESS? | 63. A TRIP TO THE PLANETS |
| 52. DETECTING RADIATION | 64. LUNAR CRATER DEMONSTRATION |
| 53. DON'T LET THE STARS GET IN YOUR EYES | 65. HOW LONG TILL WE GET THERE? |
| 54. "ROY G. BIV" | 66. COMETS |
| 55. INTERPRETING SATELLITE DATA | 67. WHAT THE ROCKS TELL US |
| 56. TILT! | |

Objectives: To demonstrate that solar energy passes through some materials and not through others; to compare the amount of electricity produced by a solar cell when light is passed through different materials in front of the cell; to identify and hypothesize how certain materials are able to transmit solar energy and others are not.

Materials: A solar cell; milliammeter or galvanometer; 5cm squares of plastic sheets in several colors - red, blue, yellow, green; wax paper; glass; tissue; foil; a pair of sun glasses; cardboard; wood; a leaf; container of water; any other material you wish to include; a 200 watt bulb with reflector or spotlight in case the sun is not shining; (Optional- a pyranometer which measures the amount of light being absorbed at any given time - to be used in place of the milliammeter); activity sheet.

Procedure: 1. Hook up your solar cell to the meter you have available. Position the solar cell facing the sun or the lamp so that you get the maximum reading on your meter.

2. Record the reading on the table from the activity sheet.

3. Test and record readings while using all of the other materials in turn.

4. Have the students rank the materials from best transmitter of solar energy to worst.

5. Have the students hypothesize about what must be true of a material to be a good transmitter of solar energy.

Extensions: Have the students identify and control any variables in their experiments which they may not have taken into account during the first try. Did results change? Try combinations of materials and compare these results with the first experiment. Compare the results with experiments on heat absorption by different colored materials. Have the students research the uses of solar power in spacecraft. Find information on the proposed projection of solar power to the earth by microwave from collectors in space. Read about the Gossamer Albatross solar powered plane and get a film about it from NASA.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

60 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Guided Discovery
ExpositoryCONCEPTS:Solar Energy
Solar Cell
Solar TransmissionSKILLS:Hypothesizing
Collecting Data
Interpreting DataRESOURCES:BK - A.4;G.1,2
FM - 33

DATA TABLE

First reading _____

Material	Reading	Material	Reading
Plastic Sheets		Wax Paper	_____
Clear	_____	Wood	_____
Red	_____	Leaf	_____
Blue	_____	Water	_____
Green	_____	Glass	_____
Yellow	_____	Tissue	_____
Foil	_____	Sunglasses	_____
(other)	_____	(other)	_____

1. According to your results, which materials are good transmitters of solar energy?
2. Name those materials tested which do not transmit solar energy.
3. What is meant by the term "transmit" as it applies to solar energy?
4. Define "translucent", "transparent" and "opaque".
5. Which of the materials you used in your experiment were translucent? Transparent? Opaque?

Objectives: To distinguish between the presence and absence of solar energy by means of a radiometer; to observe and describe the effects of low and high amounts of solar energy on a radiometer; to demonstrate that solar radiation can do work.

Materials: Paddle type radiometer (at least one or as many as one for every two students); squares of different material 30cm on a side (black paper, cardboard, cellophane in several colors); can or oatmeal container large enough to fit over the radiometer.

Teacher Background Information: The atmosphere inside a radiometer is a partial vacuum. With many of the molecules of air removed from inside the globe, those left can move about much more freely than those outside the radiometer. Each paddle inside the radiometer has a dark and a light colored side. The dark side of the paddle absorbs more heat energy than the light side. As molecules of air strike the dark side they pick up much more energy than those striking the light side. The result is that the molecules kick away from the dark side and cause a reaction in the opposite direction propelling the paddles. A good reference is The Radiometer - What Makes it Work?, Windsor Electronics Inc., P.O. Box 662, Wheaton, IL 60187

Procedure: 1. Have the students examine the radiometer for several minutes before you begin.

2. Place the radiometer on a desk or table in the sunlight and have the students observe and record what happens.

3. Place different squares of material in front of the radiometer and record the observations again.

4. Place a container over the radiometer and remove it after several minutes. Record what you observe about the radiometer immediately after it was uncovered.

What happened when the radiometer was placed in the sun? When it was shaded with different materials? When it was covered? In which direction did the paddles spin? How

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large or Small

TIME:

60 minutes

TYPE OF ACTIVITY:

Student Investigation
or Teacher Demo

TEACHING STRATEGY:

Guided Discovery
Expository

CONCEPTS:

Solar Radiation
Radiometer
Energy Absorption

SKILLS:

Observation
Inference
Collecting Data

RESOURCES:

BK - G.2

does the radiometer detect solar energy? How does the radiometer demonstrate that sunlight can do work?

Extensions: Use a light source like a slide projector and shine the light at different angles on the radiometer. Record the rotation rate of the radiometer at different angles. Relate this to the angle of the sun at different times of the year in relationship to the earth. At what angle was the rotation rate the greatest? The slowest? At what angle, in your area, would it be best to place a solar collector in relationship to the sun? At what time of the year would your collector be the most efficient? If you were going to use solar collectors on a space vehicle, (for electricity or propulsion) what provisions for the relationship of the collectors to the sun would you make? Could you use the solar energy demonstrated by the radiometer to propel a space vehicle? Why or why not?



Adapted from Dept. of
Energy, CS-0062, SOLAR
ENERGY PROJECT
ACTIVITIES, JR. HIGH
SCIENCE

Objectives: To investigate the rate at which different colored materials absorb heat; to investigate the rate at which different colored materials radiate heat; to be able to select a color which would be the best collector of heat and a color which would be the best radiator.

Materials: A radiant heat source (heat lamp or high wattage bulb); two thermometers (-10°C to 110°C); five cans of the same size and material; spray paint in several colors (red, flat black, yellow, green, white); several corrugated cardboard squares (large enough to cover the tops of the cans); a clock with a second hand or a stop watch; water at room temperature; water at 50°C or greater.

Teacher Background Information: Heat travels through a vacuum by radiation in the form of electromagnetic waves. What is more, light, also traveling in the form of electromagnetic energy, can be absorbed by certain colored materials and changed into heat energy by causing the molecules of the materials to vibrate more rapidly.

Generally, light colored materials (white or shiny) reflect most wave lengths of light and black absorbs most all wave lengths. Therefore, the molecules in a black material receive more energy than shiny material and speed up causing a heat build up.

Many experiments in school texts have students add hot water to containers of different materials to see which are the most efficient insulators. Students are sometimes suprised to find that metal containers get hot very quickly but loose their heat rapidly, also. See, through the following experiment, if the students can discover a possible reason for this. (Metal, while absorbing heat rapidly by conduction, is an efficient radiator also).

A major concern of space travelers is the build up of heat in the space craft. Currently, the Shuttle uses the cargo bay doors as giant radiators to prevent a dangerous build-up of heat. The doors are opened while in orbit to expose shiny silvered coverings which reflect the radiant heat reaching the Shuttle from the Sun in the form of electromagnetic waves. Try to relate the results of this experiment to the application of the concepts to the

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

60 minutes

TYPE OF ACTIVITY:Teacher Demo or
Student InvestigationTEACHING STRATEGY:Guided Discovery
DiscussionCONCEPTS:Radiant Energy
Solar Radiation
Electromagnetic EnergySKILLS:Experimentation
Interpreting Data
Recording DataRESOURCES:

BK - G.2

real situations encountered by space scientists.

Procedure: 1. Prepare cans in several colors with the spray paint and allow to dry thoroughly.

2. Fill two cans with equal amounts of water at room temperature.

3. Place a piece of cardboard, through which you have made a small hole for a thermometer, on top of each can.

4. Insert a thermometer into each cardboard making sure the bulb of each thermometer does not touch the sides or the bottom of the cans but extends into the water.

5. Place the cans on opposite sides of the heat source about 20cm away.

6. Record the temperature of the water in each can every two minutes for twenty to thirty minutes.

7. Now fill each can with the same amount of hot water and record the temperature every two minutes for twenty to thirty minutes.

8. Graph the results.

Which of the cans absorbed more heat by radiation? Which of the cans radiated the most heat energy? Why do you think this is so? What colors do you think would be the best for a spacecraft? Why do you think so? If you were to produce a solar collector to produce hot water, what color would be the most efficient for your device?

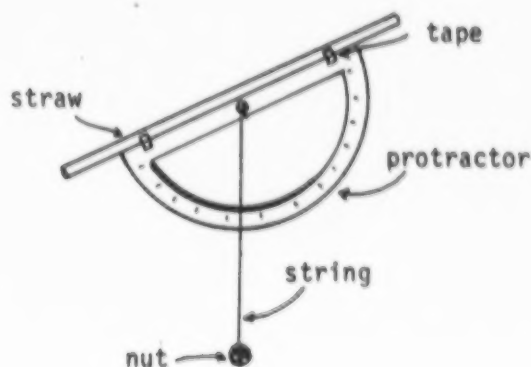
Extensions: Try the experiments using containers made of other materials than metal. Repeat the experiment using empty cans. Explain what may have caused any differences in the results. Do the experiments again placing the cans further away from the heat source. Try using the sun as the heat source.



Objectives: To learn a method of determining the latitude of your location on the Earth; to learn a method of locating the North Star.

Materials: For each student or group of students... 1 drinking straw; protractor; piece of thread; washer or other weight; cellophane tape; magnetic compass.

Procedure: 1. Tape the straw to the base of the protractor as shown in the drawing.



2. Attach the thread to the center of the base of the protractor and attach the washer to the other end.

3. Teach the students the following technique to locate the North Star. First, locate the Big Dipper (use a compass to locate the general direction of north if needed). Next, follow an imaginary line from the two stars which form the front of the Dipper (see illustration). The first star you come to in line with the "pointer" stars is the North Star.

4. Point the straw/protractor sighting device at the North Star.

5. Let the thread hang loose until it stops moving.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
50 minutes

TYPE OF ACTIVITY:
Construction
Skill Development

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Latitude
Pointer Stars
Inclination

SKILLS:
Construction
Following Directions
Recording Data

RESOURCES:
BK - A.4c;D.1,2;I
FM - 50



6. Hold the thread tight against the protractor and read the degrees.

7. Repeat the observation at least three times and record the readings. (Use the conversion table shown or subtract the readings on the protractor from 90 to arrive at the proper latitude angle.)

8. Have the students take their devices home and take readings which they will bring back to class the next day.

9. Average the readings from the class. This should be a close approximation of the actual latitude of your area.

Extension: Use the angle of latitude to construct a sundial. The angle is the same as the angle of the gnomon on a sundial for your area.

CONVERSION TABLE

Reading From Protractor	Degrees Of Latitude
105	15
110	20
115	25
120	30
125	35
130	40
135	45
140	50
145	55
150	60
155	65
160	70
165	75

Each degree of angle on the protractor
is one degree of latitude.

Objectives: To review the concepts of latitude and longitude; to gain experience locating and reporting the position of sites on Earth in degrees of latitude and longitude.

Materials: Study sheet; pencils; map of the U.S. or a globe; straight edge.

Teacher Background Information: It is essential that students be able to locate the latitude and longitude of an area on the Earth in order to use Landsat maps. The next lesson will introduce Landsat images and have students locate the position on Earth of the images supplied with the lesson.

This lesson has the students locate the position of several facilities important to NASA and the Shuttle program. See if the students can determine the common denominator of the locations following their having determined the latitude and longitude of each.

Procedure: 1. Reproduce the study sheet for each student.

2. Using a map of the U.S., have the students locate the latitude and longitude of each position marked with a circle on the study sheet.

3. Have the students record their positions on the sheet.

4. What are some possible relationships between the locations circled on the map? Find out more about the facilities which can be found at the locations marked and their relationship to the space program.

Extensions: Have the students plot imaginary flights from one coordinate to another on a map. Play a simulation game like "Flight" available from Interact, Box 262, Lakeside, CA 92040. Give students starting points, direction and duration (miles they can travel in one hop) and give the longitude and latitude of their final destination. Review lesson 57 in the "Come Fly With Me!" K-6 manual.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

45 minutes

TYPE OF ACTIVITY:

Student Activity
Skill Review

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Longitude
Latitude
Position

SKILLS:

Map Reading
Reading and
Reporting Data

RESOURCES:

BK - D.1,2,5c2,1
FM - 57

NAME _____ DATE _____



	LOCATION	LATITUDE	LONGITUDE
a.	_____	_____	_____
b.	_____	_____	_____
c.	_____	_____	_____
d.	_____	_____	_____
e.	_____	_____	_____
f.	_____	_____	_____
g.	_____	_____	_____

MAPPING A PLANET'S MAGNETIC FIELD

50

Objectives: To model how an aircraft or space craft can map the magnetic field of a planet; to be able to produce a map of the magnetic field of a planetary model.

Materials: Two maps of an area, one covered with plastic; at least one magnetic compass; a styrofoam ball; a clear sheet of acetate; an overhead projector; pen or grease pencil; several small bar magnets; iron filings in a shaker bottle.

Teacher Background Information: By flying through a planet's magnetic field, a craft can actually map a magnetic field's size, direction and strength using a magnetometer. Numerous NASA space launches, particularly in the Explorer series, have gathered such information. Specially equipped high-flying aircraft have also been used to map Earth's magnetic field and to develop the techniques used on the spacecraft.

Procedure: (Experiment A.) - 1. Place a magnet under the plain map. 2. Lay the acetate sheet on top of the map. 3. Make several passes over the map with the "magnetometer" (compass). 4. Make note of the direction of the compass needle. Use the laminated map to record the findings with a grease pencil. 5. Check your findings by shaking metal filings on the plastic sheet covering the original map.

How did your findings, using the compass, compare with the pattern formed by the filings? Does this pattern appear similar to what you would expect to find on the Earth?

(Experiment B.) - 1. Place a magnet in the styrofoam ball. 2. Set the ball on a cup so that it is supported away from the surface of a table. 3. Use the compass to make several orbital passes around the "planet". 4. Make a simple sketch of the magnetic field of the "unknown" planet. 5. You can test your findings by using the plastic sheet and iron filings again.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large or Small

TIME:

60 minutes

TYPE OF ACTIVITY:

Teacher Demonstration
or Student Activity

TEACHING STRATEGY:

Guided Discovery
Expository

CONCEPTS:

Magnetic Field
Planetary Model
Magnetometer

SKILLS:

Experimentation
Recording and
Interpreting Data

RESOURCES:

BK - A.4c;5c,d
FM - 35,36,37,38

Adapted from educational
materials available from
NASA Spacemobile program

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

45 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Guided Discovery
DemonstrationCONCEPTS:Mass
Weight
GravitySKILLS:Observation
Inference
ModelingRESOURCES:BK - A.1,5a;C
FM - 48,59,65

Objectives: To distinguish between weight and mass; to learn to compute specific gravity; to consider the effect on the weight of an object as it moves further away from the Earth.

Materials: Balance; spring scale; graduate; masses; string; object to weigh (make sure it will fit into the graduate).

Teacher Background Information: Students sometimes have a difficult time distinguishing between mass and weight of objects. Simply put, mass is the amount of matter in an object. Weight is a measure of the force of gravity on an object. We use a scale to measure weight and a balance to measure mass. All objects in the universe have a gravitational attraction for one another. The larger the mass of the object, the more gravitational attraction it exerts. This is why Mars, with a diameter of 6794 km, has a gravitational pull of about $\frac{1}{2}$ of Earth with a diameter of 12756 km. Jupiter on the other hand, has a diameter of 143,200 km and a gravity nearly 6 times that of Earth.

As the distance between two objects increases however, the gravitational pull decreases but the mass of the objects remains the same.

Teacher Demo: Have the students hold two magnets close together and feel the pull. Move the magnets further apart and feel the pull again. Attach the magnets to two toy cars and place spring scales on the other end of each car. Measure the force exerted by the magnets at different distances from each other. This experiment is a model for gravitational pull, also.

The popular notion is that when you get into orbit around the Earth that you are weightless, that is, out of the effect of Earth's gravity. Actually, you would have to get very far from the Earth not to be effected by its gravity. The Earth's atmosphere extends out some 32,000 km and is still held in place by gravity. Theoretically, you would always be under some effect of the gravity of Earth because every mass in the universe exerts an



attraction for every other mass. If you had a mass of 100 kilograms on the surface of the Earth, the Earth would exert a force of about 980 newtons on the mass, that is, it would weigh 980 newtons. You would be about 6440 km from the center of the Earth. The law of inverse squares states that, if you move to a distance twice that (12880 km) from the center of the earth, your weight would be $\frac{1}{4}$, that is, $(\frac{1}{2})^2 = \frac{1}{4}$. A distance three times the distance to the center would yield a gravity of $\frac{1}{9}$ and so on. Notice these distances are measured from the center of the Earth not from the surface. Subtract the distance to the center from the total to get the distance from the surface.

What is important here is that an object moving away from the Earth loses weight but not mass. The object above, perhaps an astronaut, would still be the same astronaut floating in space. The astronaut would not be weightless (at 6440 km above the Earth, he or she would still weigh about 245 newtons) and would still have a mass of 100 kg.

Procedure 1. Discuss with the students what we might mean by weightlessness in space. (By the way, the term micro-gravity is the proper term for the environment an object is in when in orbit)

2. Do the Teacher Demo shown above with the students and discuss the information on computation of the weight of an object as it moves away from the Earth.

3. Fill a 25 or 50 ml graduate half full with water. Mark the level.

4. Attach a thread or string to a mineral sample or a lead sinker and suspend it from a spring scale. Record the weight.

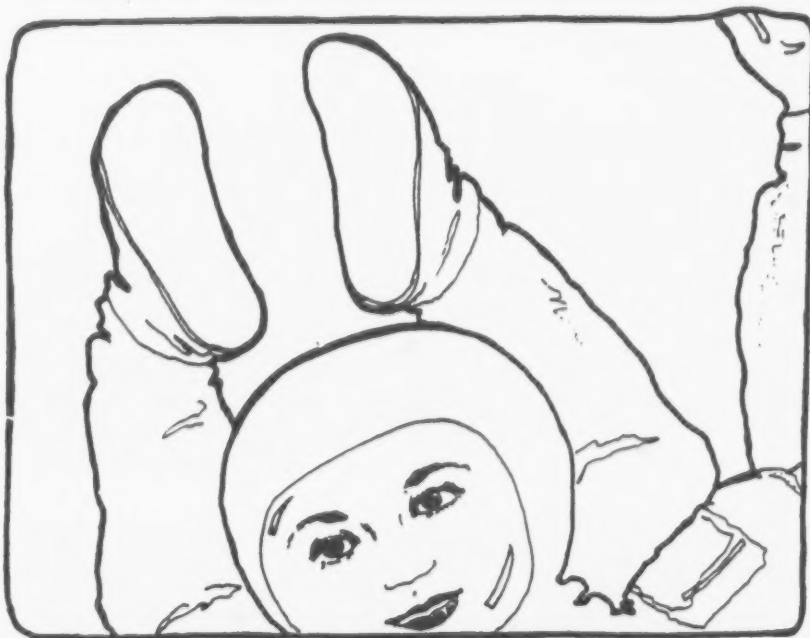
5. Lower the sample into the graduate and weigh again.

6. Subtract the wet weight from the dry weight.

7. Divide the difference into the dry weight. The result is the specific gravity.

The specific gravity is useful in the identification of rocks and minerals. This information will be useful in a future lesson.

Extensions: Have the students consider the relationship between the bouyancy of an object in water and the equalization of forces of gravity by orbiting (cetrifugal force) around a planet. Review Newton's laws and Kepler's laws and their application here. Have the students determine at what distance from the Earth the pull of gravity would be less than 1 newton.



DETECTING RADIATION

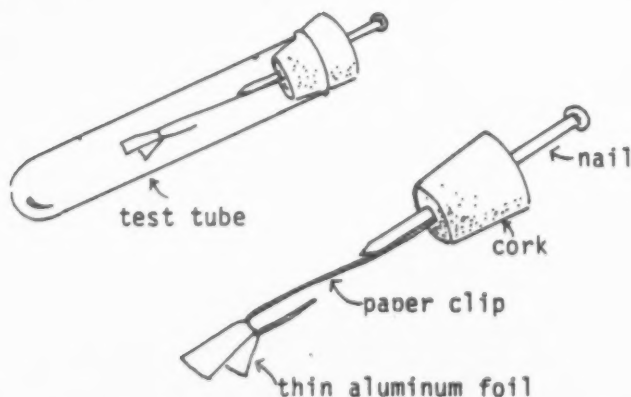
52

Objectives: To understand that radium can be detected; to understand that satellites use radium detecting devices.

Materials: Test tube; small cork; small nail; paper clip; aluminum foil strips; alcohol; glue.

Teacher Background Information: Since radiation is so harmful to humans, unmanned NASA satellites are being used in space to detect the amount of radiation present. The following activity should help students to understand the necessity for detecting radiation and one type of instrument included on many radiation-studying satellites.

Procedure: Before class, push the nail and paper clip through the cork together. Take aluminum gum wrapper and cut in half, lengthwise (1/2" x 3"). Soak strips in alcohol to dissolve glue and peel off paper backing. Assemble as illustrated: nail, cork, paper clip - touching nail, test tube; aluminum foil - glued onto paper clip.



With the class assembled, demonstrate the presence of radioactivity by taking a comb and rubbing it on some wool and touching it to the nail sticking out of the test tube. Have students note what happens to the foil leaves.

• What causes the static electricity? (Rubbing the comb on wool generates static electricity, covering the comb with extra electrons.)

• When the comb is touch to the nail, what happens? (Electrons are transferred down the nail to the foil

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
60 minutes

TYPE OF ACTIVITY:
Teacher Demonstration

TEACHING STRATEGY:
Guided Discovery
Discussion

CONCEPTS:
Radiation
Detection
Radiometer

SKILLS:
Observation
Inference
Interpreting Data

RESOURCES:
BK - A.2c,3a;D3b

leaves.)

• Why do the foil halves push away from each other and spread apart? (Because equal charges repel - in this case, negative and negative.)

You can cause the leaves to collapse again by removing the negative charge. This is demonstrated by rubbing a glass rod on a polyethylene plastic bag and touching the nail with the rod. The rod will have been charged positive by removal of electrons. Talk with the students about why the leaves went back together. Make sure they understand that the removal of electrons causes a positive charge and the leaves go back because fewer electrons are present.

Radiation can also cause electrons to be removed. To demonstrate the removal of electrons through radiation, set up the demonstration again but, after the leaves have separated, wait a period of time. The students will see that the halves will collapse on their own.

This is a result, in part, of cosmic rays streaming through the jar, ionizing some of the air, discharging the foil. The collapse speed is a measure of the number of cosmic rays entering the jar.

Other forms of radiation which normally are not present will cause the same result. You can show this by holding a radium dial wristwatch (If you can find one!) to the glass bottle or by using a uranium source. What happens to the halves of foil?

Explain to the students that this type of instrument has been included on many of the radiation-studying satellites.

Through discussion and/or reading, find more complete answers to some of the following questions:

1. What is radioactivity or when is an atom radioactive?
2. What is a cosmic ray? How fast does it travel?
3. What results would you expect if a solar storm were to erupt on the Sun? Can solar storms be predicted? Why would we want them to be?
4. What is ionization?



Objectives: To relate the flashes sometimes seen in your eyes to cosmic radiation; to review and strengthen the concept of radioactivity.

Materials: The radioactivity detector from the previous lesson; a radioactive source (radium dial watch); a Geiger counter (optional).

Teacher Background Information: An unexpected effect of cosmic rays on humans was first noted on the Apollo 11 mission to the Moon in 1969. Astronaut "Buzz" Aldrin reported that he kept seeing flashes of light while his eyes were closed. On later flights, astronauts counted these flashes and Bill Pogue (on Skylab in 1973) saw eight flashes per minute. T. F. Budinger, the Principal Investigator for Experiment MA-106, collected descriptions of these flashes and did some experiments with high-energy ions shot out of a cyclotron in his laboratory. He knew exactly what kind of particles were in the cyclotron beam and what energy they had as they entered the heads of the volunteers. If Budinger aimed the beam through the brain, the volunteer did not see a flash. It was only when the high-energy ions passed through the eye that flashes were seen.

The many different shapes and sizes of flashes reported by the astronauts in space and by the volunteers at the cyclotron are shown in the study sheet. These different shapes and sizes complicate the explanation of how the flashes are produced. The simplest idea is that a cosmic ray causes a flash when it passes through the eye's "detector," the retina. The retina is a region at the back of the eyeball where nerve endings are sensitive to the light focused there by the lens at the front of the eye. The cosmic ray ionizes a few atoms or molecules, which produces a signal in the optic nerve. This signal is interpreted by the brain as a "single star" or perhaps a "comma." The "diffuse cloud" flashes seem to be something different. (See illustration)

The "long streak" might be caused by a cosmic ray that crosses along the surface of the retina. Double stars and double streaks are most probably caused by a

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large or Small

TIME:
60 minutes

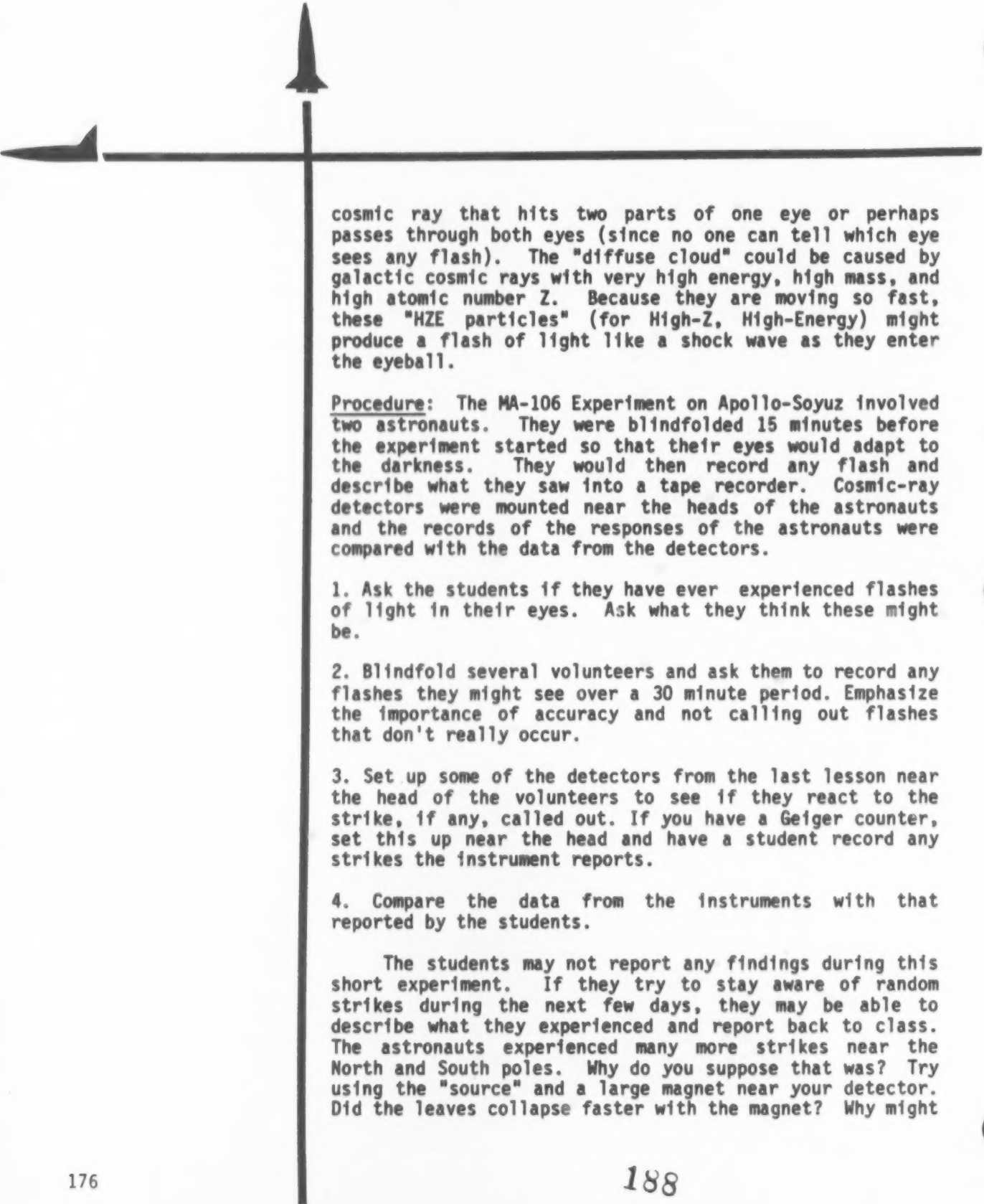
TYPE OF ACTIVITY:
Teacher/Student
Demonstration

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Radiation
Radioactivity
Detection

SKILLS:
Reading for Information
Observation/Inference

RESOURCES:
BK - A.5a,c



cosmic ray that hits two parts of one eye or perhaps passes through both eyes (since no one can tell which eye sees any flash). The "diffuse cloud" could be caused by galactic cosmic rays with very high energy, high mass, and high atomic number Z. Because they are moving so fast, these "HZE particles" (for High-Z, High-Energy) might produce a flash of light like a shock wave as they enter the eyeball.

Procedure: The MA-106 Experiment on Apollo-Soyuz involved two astronauts. They were blindfolded 15 minutes before the experiment started so that their eyes would adapt to the darkness. They would then record any flash and describe what they saw into a tape recorder. Cosmic-ray detectors were mounted near the heads of the astronauts and the records of the responses of the astronauts were compared with the data from the detectors.

1. Ask the students if they have ever experienced flashes of light in their eyes. Ask what they think these might be.
2. Blindfold several volunteers and ask them to record any flashes they might see over a 30 minute period. Emphasize the importance of accuracy and not calling out flashes that don't really occur.
3. Set up some of the detectors from the last lesson near the head of the volunteers to see if they react to the strike, if any, called out. If you have a Geiger counter, set this up near the head and have a student record any strikes the instrument reports.
4. Compare the data from the instruments with that reported by the students.

The students may not report any findings during this short experiment. If they try to stay aware of random strikes during the next few days, they may be able to describe what they experienced and report back to class. The astronauts experienced many more strikes near the North and South poles. Why do you suppose that was? Try using the "source" and a large magnet near your detector. Did the leaves collapse faster with the magnet? Why might

it be important to explore this phenomenon?

Extensions: Have the students read about the experiments carried out to gather information on these flashes. What other radiation effects have been explored in relationship to astronauts? to pilots? Do pilots who fly commercial jets at high altitudes experience the same amounts of radiation exposure as astronauts? Why or why not? Have the students explore high energy particles and their nature.

Short streak



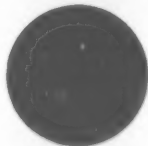
Star
(single light
point)



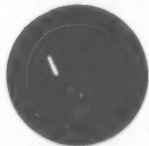
Long streak
(thin line
of light)



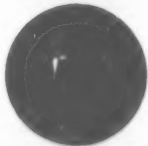
Double star
(double
light points)



Hot dog
(wide line
of light)



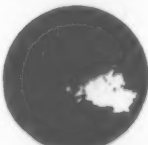
Comma
(teardrop
shape)



Double streak



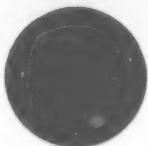
Cloud
(diffuse)



Supernova
(very bright
flash)



Snow
(more than
five short
streaks)



Shapes and sizes of reported light flashes. These 10 pictures were sketched to illustrate flashes reported by astronauts and by volunteers in the cyclotron laboratory.

Illustration courtesy NASA

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

2-45 minute periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Guided Discovery
ExpositoryCONCEPTS:Spectrum
Spectrography
ElementsSKILLS:Experimentation
Recording and
Interpreting DataRESOURCES:BK - A.4c;D.1,2
FM - 57

Objectives: To demonstrate that various elements can be distinguished by their light spectrum; to relate the experiment to the OAO satellite.

Materials: Mailing tube; aluminum foil; alcohol burner; diffraction grating or prism; scissors; pliers; straightened paper clips; elements such as: table salt - sodium chloride, boric acid - boron, copper sulfate - copper, limewater - calcium, lithium, barium and strontium.

Teacher Background Information: The Orbiting Astronomical Observatory (OAO) is an unmanned satellite designed to give astronomers their first sustained look into the universe from above the obscuring and distorting effects of the Earth's atmosphere. The OAO is the largest of the NASA scientific satellites under development and weighs nearly four thousand pounds. It is also the most electronically complex unmanned spacecraft ever developed by the U.S. It contains more than 440,000 separate parts and 30 miles of electrical wiring.

One thousand pounds of the weight is electronic astronomical observing instruments. It is a 10-foot long, eight-sided cylinder, seven feet wide. With the solar panels extended, the overall width of the spacecraft is 21 feet.

Future OAO spacecraft will have such a precise control system for pointing the scientific instruments that it could look at the width of a pencil 10 miles away. This precision is possible because of the six telescope star trackers mounted on the main body of the spacecraft.

The telescopes aboard the spacecraft will be used for several things. They will help map certain parts of the sky now hidden by direct clouds; clearer views of the planets will also be possible. They will make studies of stars to determine their chemical composition and learn more about the birth of stars. There will also be experiments which are concerned with the study of x-ray and gamma ray spectral regions. Finally, the telescopes will study stars and nebulae in the ultraviolet spectrum not visible from the Earth.

The following activity should help students to

understand more about using the simple glass prism to show the spectrum and demonstrate how elements can be distinguished by their specific light spectrum.

Procedure: 1. Ask the students to name the seven colors which make up the visible spectrum. "Roy G. Biv" is one way of helping students remember the colors: red, orange, yellow, green, blue, indigo and violet. Use a prism or diffraction grating or discuss a rainbow to demonstrate what white light is made up of. Talk about ultraviolet light being near the blue band of the visible light portion of the spectrum. Discuss the damage ultraviolet light can do. Why do we use sunglasses on very bright days? Why do we burn if we stay in the sun without protection for too long?

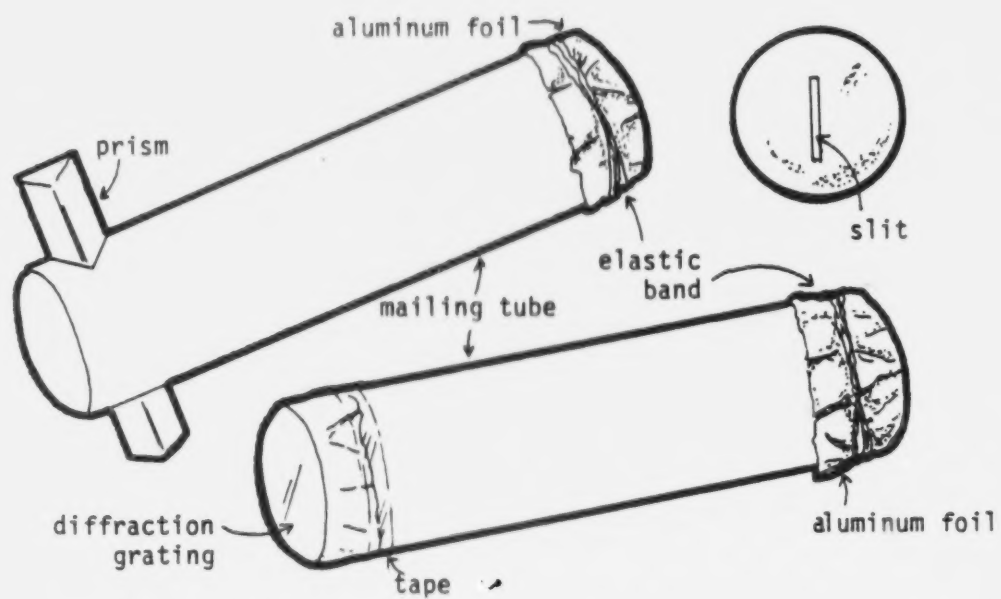
2. If you have fluorescent minerals or fluorescent chalk, have the students observe the effect of ultraviolet light when you shine a light on them. Ask the students why, if the sun gives off so much ultraviolet light, we don't burn up. Tell them that the OAO will study ultraviolet light that cannot penetrate our atmosphere by looking at it above the atmosphere and this information could lead to revisions of present theories of stellar origin and evolution.

3. To help students understand the spectrum and how various elements can be distinguished by their light spectrum, have the students

- a. take the prism or diffraction grating and place it in one end of the mailing tube;
- b. attach aluminum foil on the other end with elastic
- c. cut a slit in the aluminum foil;
- d. light the alcohol lamp;
- e. place a clean paper clip in the pliers, dip into element to be tested and place over flame;
- f. hold prism end up to the eye and observe color spectrum of specific element;
- g. discuss the visible spectrum that is observed and record in notebook the name and the colors observed;
- h. change the paper clip for each element tested and repeat the test for all the elements you have.



SPECTROSCOPE



INTERPRETING SATELLITE DATA

Objectives: To gain skill in the interpretation of satellite transmitted data about the earth; to consider the applications of data available from satellites to earth resource management; to consider the implications of earth data from satellites to the exploration of other planets.

Materials: Colored pencils (optional); study sheet on page 183; Landsat photos or one of the reference books suggested in the reference section of this lesson.

Teacher Background Information: Landsat views the United States every 18 days sending back information in the form of "pixel" pictures which can be printed out in a format similar to the one on the study sheet or the computer can generate a photograph by interpreting the data and translating it into picture form. Each pixel segment, represented by the symbols: +, X, -, 0, etc., covers an area 57 by 79 m (4503 m² or about .45 hectares). An actual Landsat scan is 185 km wide so the study sheet is only a small portion of an entire Landsat scene. It has been shown that Landsat can yield timber management maps with about 90% accuracy compared to actual conditions on the Earth. The accuracy of the data from Landsat is checked by actually verifying the information with on-site inspections of the photographed area. This technique, called "ground truth", is very important in developing interpretation skills for information gained when exploring other planets. This lesson allows students to experience some of the skills needed to interpret a computer generated map transmitted by the Landsat satellite. Additional information and experiences can be found in an excellent NASA publication, *Mission to Earth: Landsat Views of the World*, NASA SP-360.

Procedure: Have the students work in pairs or individually. Reproduce the map on the study sheet for each group of students. Have the students determine what kind of information can be obtained from this type of map. Tree canopy refers to the development of branches; the more closed the canopy, the larger and more mature are the trees. Open canopy indicates that more ground shows through the branches of younger, smaller trees. Clearcut

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Individual or Pairs

TIME:

60 minutes

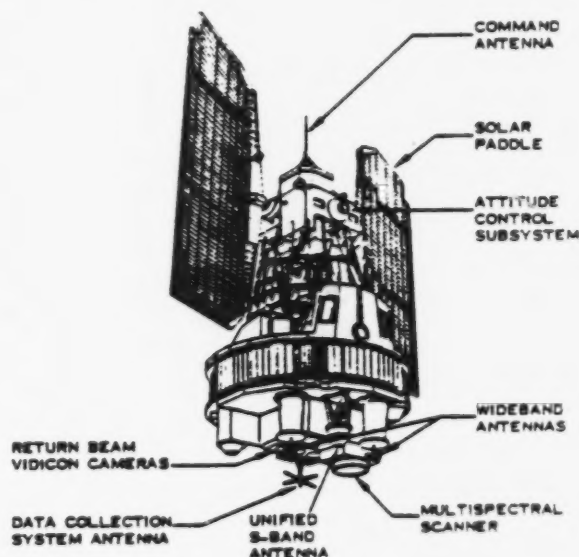
TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Expository
Guided Discovery**CONCEPTS:**Landsat
Earth Resource
Management**SKILLS:**Interpreting Data
Observation
Following Direction**RESOURCES:**BK - A.3,4;D.3a
FM - 5,57,64

refers to areas where all standing trees have been removed.) You may wish to have the students color in the areas on the map to designate each category listed above.

1. What is the total area represented by the map? Total area of hardwood? Soft wood?
2. Which area is beginning to grow young trees? has young trees? has older, mature trees?
3. How does the area which has been clear cut compare to the selectively cut area? the most recently harvested?
4. Describe the advantages and disadvantages of both selective and clear cutting.
5. What do you suppose are the areas for which the computer provided no classification? What may have caused this?
6. What might be the value of these maps for timber managers, lumber companies and paper companies?
7. How might such maps aid an environmental protection agency? A space scientist exploring other planets?



LANDSAT Work Sheet

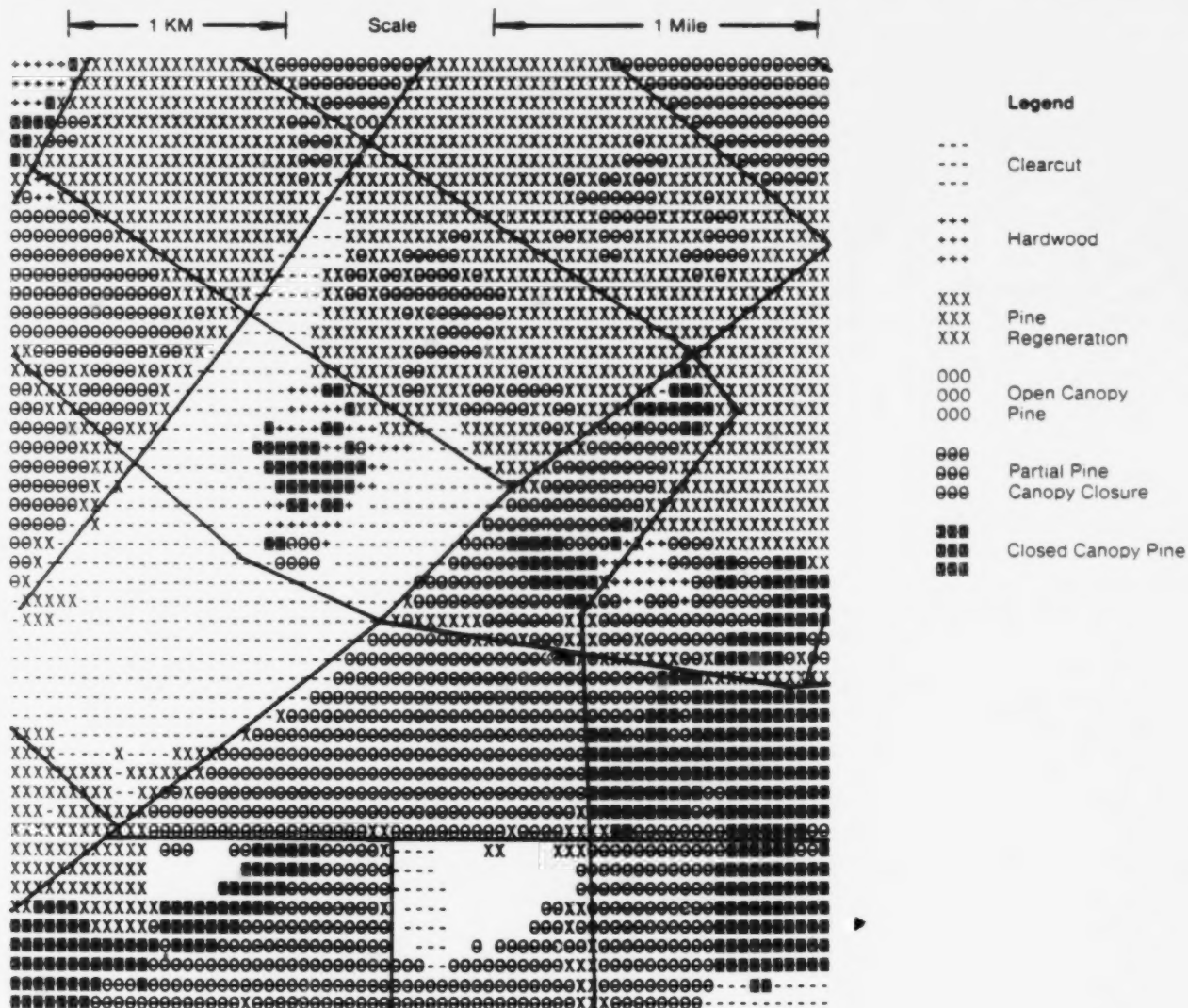


Figure. Computer generated map which illustrates the use of Landsat data in forest resource management.

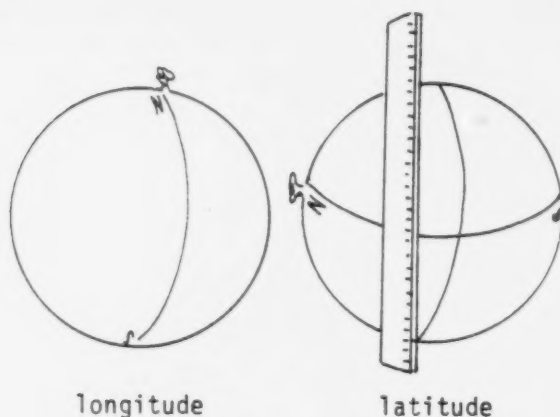
Illustration courtesy NASA

TILT!

Objective: To demonstrate that satellites pass over different parts of the Earth on each revolution because the Earth is rotating beneath it.

Materials: Yardstick; large balloon (light in color and able to inflate to at least 15" in diameter or larger - circular in shape); two rubber bands; two felt markers (one black and one red); one large map of the world (wall map).

Procedure: 1. Inflate the balloon. Tie it off with a rubber band.
2. With a black felt marker, mark the North Pole (N) at the nozzle end and the South Pole (S) directly opposite.



3. Lay the yardstick on the table and line up "N" and "S" Poles. Have a student support the balloon while you draw a straight line of longitude from "N" to "S" Pole with the black felt marker.

4. Turn the line of longitude perpendicular to the yardstick. Now support the balloon and ask a student to draw a line of latitude around the exact center of the balloon with a black felt marker. Ask the class which line of latitude this represents.

5. Refer to the world map and locate 80° W longitude and 29° N latitude. Ask them where this is

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Large

TIME:
45 minutes

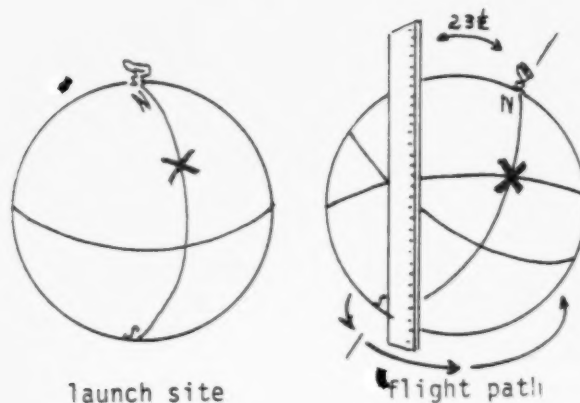
TYPE OF ACTIVITY:
Teacher/Student
Demonstration

TEACHING STRATEGY:
Guided Discovery
Discussion

CONCEPTS:
Earth Rotation
Satellite Track
Axis Tilt

SKILLS:
Observation
Inference
Interpreting Data

RESOURCES:
BK - A.4
FM - 57



6. Ask the class if anyone knows what the tilt of the earth's axis is. ($23\frac{1}{2}^\circ$)

7. Approximate this tilt using the yardstick as a guide.

8. Ask someone to hold the red felt marker on the red X while another student rotates the balloon to form a complete circle keeping the proper degree of inclination by using the yardstick below, and his or her line of sight.

Ask such questions as these:

- What does the balloon represent?
- What does the line of latitude represent?
- How many times does the orbital path cross the line of latitude?
- What would be the land mass crossed south of the line of latitude? Make a rough sketch of that land mass on the balloon.
- What other land masses would be crossed by the orbital path? Sketch those land masses, also.
- Where would be good locations for tracking stations? You can have the students place dots to represent them on the balloon and have them record the location, the latitude and the longitude of several. Talk with the class about what things have to be considered before putting tracking stations in certain places.

Adapted from educational materials available from NASA Kennedy Space Center Teacher Resource Room

WEATHER FRONTS MOVE

Objective: To measure the speed at which a front or a high moves.

Materials: Activity sheet (following); cm ruler.

Teacher Background Information: One of the ways meteorologists can predict what the weather will look like for a particular area over the next few days, is to measure the speed at which the weather fronts are moving. This is helpful for pilots, for example, when they want to make sure that a front bringing poor weather is not going to move so fast that it interferes with getting from one place to another or in judging when a particular front will move out and provide good flying weather behind it. For these reasons, pilot training entails many hours of learning how weather works and the symbols used to communicate the weather picture.

Procedure: 1. Hand out the activity sheets to each student.

2. Talk with the class about the need for predicting weather and the notion that one of the criteria used for prediction is the speed at which fronts move.

3. Discuss what each of the symbols means and clarify any concern about the directions on the activity sheet.

4. When the students have finished, have them get together in small groups of 4-5 to compare the answers they came up with. Ask them to rethink any that now seem out of line.

Extension: Bring in the weather maps from the local newspaper for two consecutive days. The symbols used may differ from the one shown in the activity sheet, but students can repeat the activity using the same method of measurement. Then, have them make their own prediction about the following two day's weather for their area. Does the paper predict the same thing? See how close their predictions come to what actually happens.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
60 minutes

TYPE OF ACTIVITY:
Student Investigation
Discussion

TEACHING STRATEGY:
Guided Discovery
Expository

CONCEPTS:
Weather Front
Weather Map
High/Low Pressure

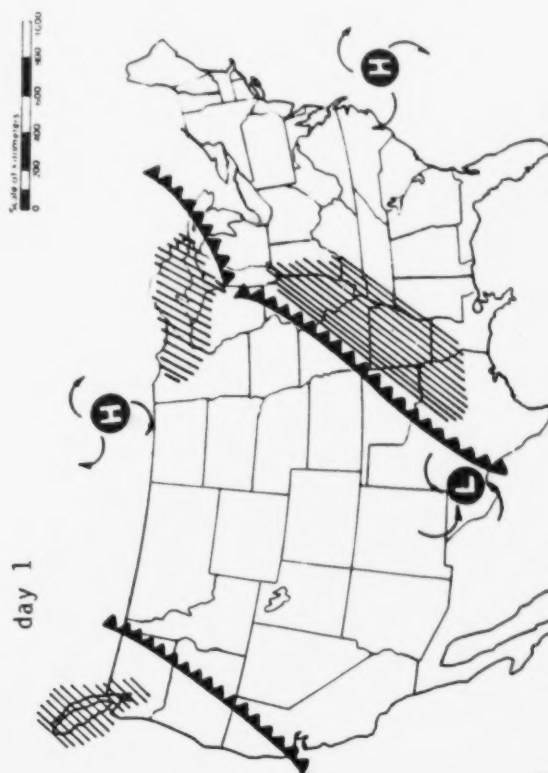
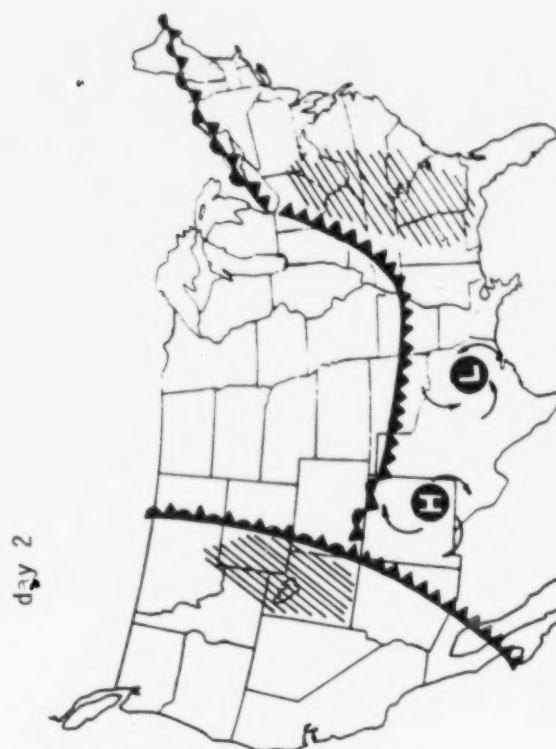
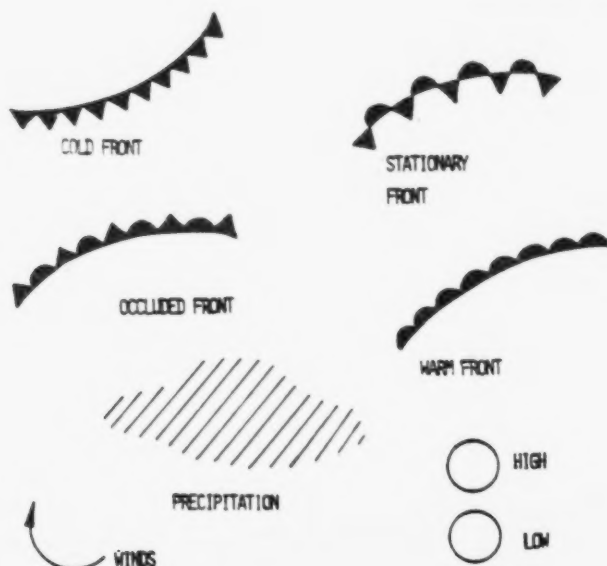
SKILLS:
Reading for
Information
Interpreting Data

RESOURCES:
BK - A.4;B.1,2;H
FM - 2,4,5,6,7,9

WEATHER FRONTS MOVE.... (activity sheet)

1. Locate the front along the West Coast on the map of Day 1.
2. Calculate and record the distance in km that the front moved in one day.
3. Divide the distance found in step 2 by the number of hours in one day. What does this give you? _____ km/hr
4. Find the high in Canada on the map of Day 1. Repeat steps 2 and 3 to find out how fast the high is moving. _____ km/hr.
5. Describe the general direction or path of the highs, lows and fronts on the maps.
6. Describe the wind direction near lows and highs on the maps. Use these terms: in, out, clockwise, counter-clockwise.
7. What has happened to the north end of the cold front in the West by Day 2?
8. What are the weather conditions in Michigan on Day 1?
9. Predict the weather where you live for the day after Day 2.

● adapted from Scott, Foresman
Earth Science



READING AND PLOTTING WEATHER DATA

Objective: To practice reading and using the standard weather symbols used around the world.

Materials: Activity sheet and pencils.

Teacher Background Information: Understanding and predicting the weather is a vital concern of aviation and space for poor weather can cause delays and cancellations of flights, at best, and loss of life, at worst. As a protection from misunderstanding, weather symbols have been standardized around the world and meteorologists receive and transmit weather information using these symbols.

The following activity deals with reading some of the more common symbols and using them to draw weather station map entries for three cities.

Procedure: Hand out the activity sheets to each student.

Then, 1. Discuss some of the reasons why the aviation and space industry must obtain, and thoroughly understand, reliable weather data.

2. Discuss the need for meteorologists to have standard international symbols to relay weather data.

3. Have the class look over the Weather Symbol Table together. Look at the similarities and get a feeling for what the various symbols stand for.

4. Clarify the directions on the activity sheet so students understand how to proceed with their drawings. Unless they have had some prior experience with this, drawing the weather station entry may seem a bit complicated at first. The important part is to understand the symbols and to realize how important it is to be absolutely accurate in using them.

Extension: Obtain a weather service map. Have the students choose a city and write a paragraph telling what the weather picture is for that city on a specific day. You can request maps from the Weather Service Bureau at a major airport nearby or from a local TV station which uses the National Weather Bureau service.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

60 minutes

TYPE OF ACTIVITY:

Student Activity
Skill Practice

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Weather Symbols
Weather Maps
Meteorology

SKILLS:

Reading and
Interpreting Data
Plotting Data

RESOURCES:

BK - A.4c;H;I
FM - 1,2,4,7,8,9

READING AND PLOTTING WEATHER DATA

(ACTIVITY SHEET)

a

SOME COMMON WEATHER SYMBOLS	
Precipitation	Some type of high clouds
 Fog  Snow  Rain  Thunder storm	 Scattered cirrus  Dense cirrus in patches  Veil of cirrus - covering sky  Cirrus - not covering sky
Wind speed and direction	Some types of middle clouds
 1 to 3 mph  4 to 7 mph  8 to 12 mph  13 to 18 mph  19 to 24 mph  25 to 31 mph	 Thin stratus layer  Thick stratus layer  Thin stratus in patches  Thin stratus in bands
Sky coverage	Some types of low clouds
 No cover  2/10 to 3/10  1/2  7/10  Complete overcast	 Cumulus of fair weather  Cumulus of bad weather  Stratus of fair weather

Procedure: Examine the Weather Symbol Table (a). Then, draw a complete weather station map entry for Detroit, Michigan. Start by drawing a small circle. Use the Weather Station Model (c) as your guide. Convert the information in b to weather map symbols. The numbers or symbols on your drawing should be in the same position as they are shown in c. For example, the symbol for type of low clouds appears just below the circle, the symbol for type of high clouds appears left and above the circle and the air pressure reading appears directly right of the circle. The wind speed and direction symbol is the only symbol found in different locations around the circle, since it indicates the direction of the wind in relation to the circle. (The direction of the wind in the example (c), is from the southwest.)

Repeat your procedure for Cape Canaveral and San Francisco.

1. What is the weather like in the three stations in b?

2. Why is the change in air pressure important?

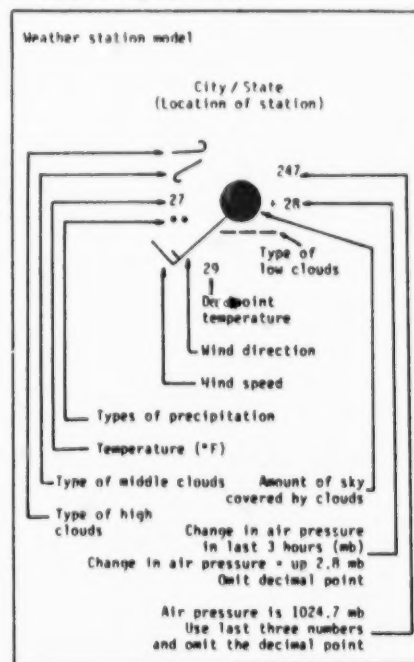
3. What type of change in air pressure would you find at a station where a cold front recently passed through?

4. Do you think the people at Kennedy Space Center would be happy with the weather indicated here if they had a Space Shuttle launch planned?

b

LOCATION OF STATION	DETROIT, MI	CAPE CANAVERAL, FL	SAN FRANCISCO, CA
Temperature in (°F)	68	66	50
Precipitation	None	Rain	Fog
Wind speed in miles per hour	12	23	6
Wind direction	Northwest	Southwest	West
Dew point temperature	63	68	60
Cloud type:			
High	Scattered cirrus	Veil of cirrus	Dense cirrus
Medium	Thin stratus layer	Thick stratus layer	Thin stratus in bands
Low	Cumulus - fair weather	Cumulus - bad weather	Stratus of fair weather
Sky Coverage	2/10	Complete overcast	7/10
Air pressure (mb)	1012.4	1002.4	1015.1
Change in air pressure (mb)	Up 1.2	Down 2.6	Down 1.8

c



ASTRONOMICAL UNIT

Objectives: To gain experience with the concept of Astronomical Unit (A.U.); to construct a scale model of the solar system using A.U.'s.

Materials: 1 meter stick per group; tape measure 40 meters long (optional); 1 adding machine tape per group; pencil.

Teacher Background Information: In the study of astronomy, astronomers use a convenient unit of measurement known as an Astronomical Unit or A.U. The A.U. is a short cut in describing distances in the solar system. The distance between the Sun and the Earth is, on the average, 149,600,000 kilometers (93 million miles.) Astronomers call this distance between the Earth and the Sun 1 A.U. An object twice the distance away would be called 2 A.U.'s away and so on. The A.U. is really a scale showing distance. The scale is 1 A.U. = 149,600,000 kilometers.

Procedure: 1. Divide the students into groups of 4 or 5.
2. In a hallway, a gym or outdoors have each group extend their 40 meter adding machine tape.
3. Identify one end of the tape as the Sun.
4. Measure one meter from the Sun end and label that point as the Earth.
5. Use the diagram below to mark the positions of the rest of the planets and the asteroid belt as fractions or multiples of 1 A.U.

PLANET	A.U.'s
MERCURY	.387
VENUS	.723
EARTH	1.000
MARS	1.524
asteroids	2.800
JUPITER	5.203
SATURN	9.523
URANUS	19.164
NEPTUNE	29.987
PLUTO	39.370

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
45 minutes

TYPE OF ACTIVITY:
Student Activity
Modeling

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Astronomical Unit
Solar System
Distance

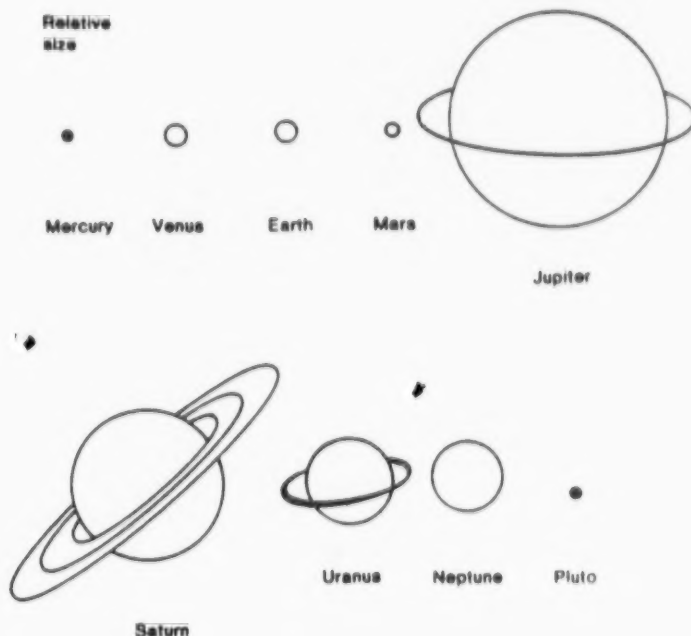
SKILLS:
Modeling
Measuring
Plotting Data

RESOURCES:
BK - A.2c;D.1,4,5
FM - 32,35,36,50

Extensions: Once the students have the relative distances on their tapes, try to find a place in the school where the scale can be permanently displayed. Arrange to paint the planets' names and or images in proportional sizes at the given distances.

NOTE: It is nearly impossible to get the size of the planets and the distances proportional to one another at the same time in a school building. The relative sizes in the illustration below, while proportional to one another, would require that Pluto be nearly a mile from the Sun. Lesson # 45 in the K-6 "Come Fly With Me!" manual gives an easy to use scale of sizes.

If a larger scale is desired, why not have the students compute the distances and make arrangements in your town to place a picture or a notation about the scale and the project at a building at the appropriate distance from your "Sun" at the school.



Adapted from educational materials available from NASA Spacemobile program

PARALLAX ONE

Objective: To provide students with an understanding that near objects appear to change their positions more than distant objects when the position of the observer changes.

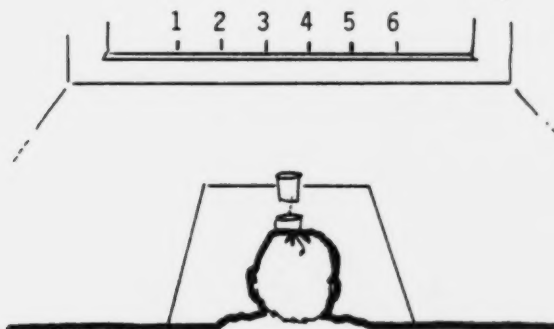
Materials: Two paper cups; meter stick; table or desk; chalkboard or wall; chalk.

Teacher Background Information: As we drive down the highway and look at a tree in the field, the tree seems to change position against the woodland in the distant background. If the tree is close to the road, this apparent shift is great; if the tree is close to the woods, its apparent shift is small.

Such a shift in apparent position is called parallax and is useful in determining the relative distance to far off objects such as stars. Astronomers observe a star's location with respect to more distant stars. They will sight the more distant star with a closer star and then wait a few months while the earth moves in its orbit around the Sun. Then, they observe the star's position again. Nearby stars appear to shift to a slightly different position with respect to the more distant one. This shift is called parallax and it can be measured. The nearer star will appear to shift further than more distant stars and the very distant stars may have shifts too small to measure.

This activity gives students the opportunity to see how parallax works. The activity which follows, Parallax Two, provides students with the opportunity to do some calculations regarding parallax.

Procedure: Have the students put two paper cups about 30cm apart on the desk or table, as shown in the illustration.

**SUBJECT:**

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

45 minutes

TYPE OF ACTIVITY:Teacher Demo or
Student Investigation**TEACHING STRATEGY:**Expository
Guided Discovery**CONCEPTS:**Parallax
Measuring Long
Distances**SKILLS:**Observation
Measuring
Plotting Data**RESOURCES:**

D.1

Make 6 chalk marks 50 cm apart on the wall or chalk board on the other side of the classroom and number them 1 through 6 as shown in the illustration.

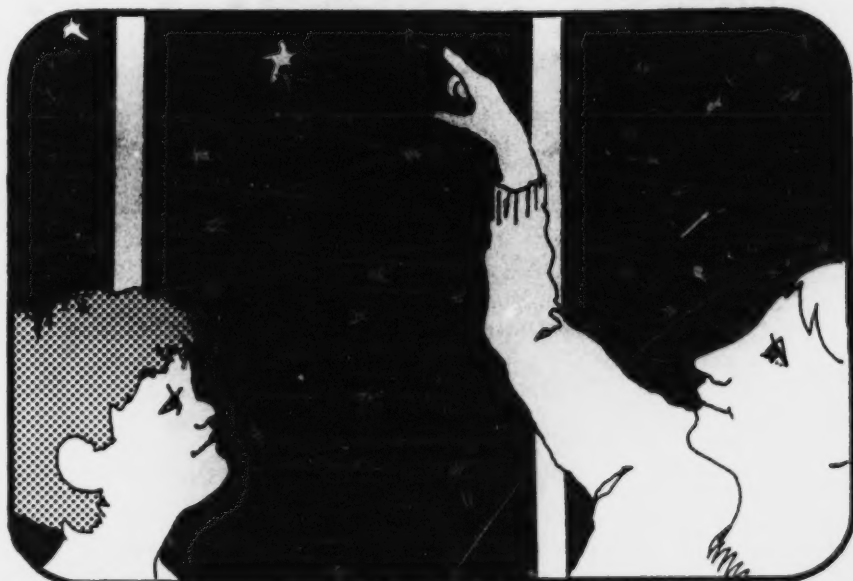
1. Have a student place himself or herself 1m behind the table like the student in the illustration. Make sure the eyes are level with the paper cups.

2. Ask the student to draw a picture of the paper cups as they appear from that vantage point. Include the positions of the chalk marks. Then,

3. Have the student move 1m to the left and draw the paper cups as they appear now. Show their position in relation to the chalk marks on the wall. Have the student move to two other positions and draw what is seen.

4. Ask the students to think about these questions:

- a. What do the two cups represent?
- b. When the student shifts position, what does that shift represent?
- c. How are the drawings different from each other?
- d. Which paper cup appeared to move the most?
- e. What effect does the observer's position have on the apparent position of the things seen?



Adapted from NASA
educational materials

PARALLAX TWO

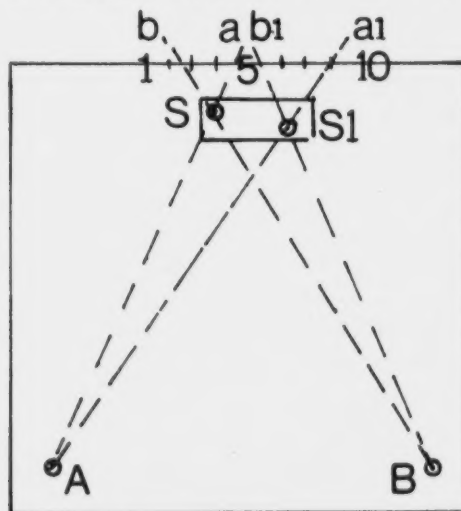
61

Objective: To learn how parallax can be used to determine the relative distance to the stars; to calculate, using parallax, the distance to an object in the classroom.

Materials: Meter stick; 2 styrofoam balls; chalkboard; block with mounted protractor; ruler; graph paper.

Teacher Background Information: Before class begins, draw and number about 10 vertical lines on the chalkboard with 30cm between them.

Procedure: Have the students prepare a piece of graph paper by drawing their classroom to scale. You can discuss with your students the appropriate scale to use given the size of the classroom. Ask the students to use a whole sheet of paper and to indicate the positions of the numbered chalkboard lines on the drawing



Now,

1. have students move to the back left hand corner of the room (indicate this as point A on their drawing) and sight along the edge of a ruler at "star" S. Have them note the number of the line that appears to be in line with "star" S and indicate this position on their paper as "a." Have them draw a dotted line from A to "a."

2. Without moving, have the students sight at star S1. The students should note the number of the line that appears to be in line with star S1 as a1 and draw a dotted

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large or Small

TIME:

45 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Parallax
Relative Distance
Relative Motion

SKILLS:

Measuring
Graphing
Plotting Data

RESOURCES:

BK - D.1,2

line from A to a1.

3. Have student move to the right hand back corner of the room and mark this point on his/her paper and sight along the ruler at star S and then star S1 indicating the apparent positions of the chalk lines on the board as b and b1. Draw lines from B to b and from B to b1.

4. Have students draw a small circle where line Aa crosses Bb and indicate this circle as S. Have them draw another circle when line Aa1 crosses Bb1 and indicate this S1.

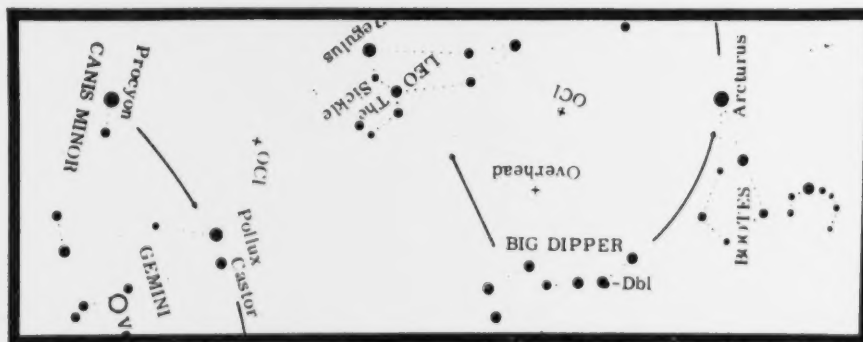
5. Have students measure the distance from the back of the room, to the positions of S and S1 on their paper and calculate these distances using the same scale you came up with earlier. Now, have them measure the actual distance from the back of the room to S and to S1 with a meter stick.

6. Discuss the following with your students as a way to apply this activity to using parallax to measure distances to stars:

On July 1, consider the earth's position as A. We sight on two nearby stars S and S1 against their background of stars. On January 1 we consider the earth's position as B and we sight on the same two stars against their backgrounds.

What is the distance between points A and B?

We notice that the apparent shift behind star S is very slight, but the apparent shift behind star S1 is twice as great. Which star is closest to the earth?



Adapted from NASA
educational materials

Objectives: To see how a radio telescope works; to understand some of the reasons for using radio telescopes.

Materials: Transistor radio; umbrella; heavy-duty aluminum foil (to line the inside of the umbrella).

Teacher Background Information: "Our galaxy, the Milky Way, contains between 100 billion and 300 billion stars. One star out of every 18,000 has the potential for supporting a planet similar to Earth. Yet, even if we start with the lowest possible galactic number of 100 billion stars, this means that just within the Milky Way, some five million stars could meet the basic requirements for life. Beyond our own corner of the universe, the hundreds of billions of other galaxies might harbor millions of other suns supporting millions of other Earth-like planets, as well.

Most crucial to the question of extraterrestrial visitations is the problem of interstellar travel. The distance to even the nearest star is so great as to render space travel, by any means we now know, impossible within a human lifetime. A more likely form of contact with extraterrestrial intelligence (if it exists) may be through long-distance messages rather than actual visitations; radiowave transmissions now seem the most likely method of instellar communication."

Taken from, "Life in the Universe: an Introduction to the Search for Extraterrestrial Intelligence," a brochure available from Public Affairs Office, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MS 02138

Procedure: First, place the radio on the desk or a table in the classroom. Starting at one end, find weak stations on the radio and write down the dial numbers of five of them.

Next, make a model radio telescope by opening the umbrella and lining the inside with sheets of aluminum foil.

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small or Large

TIME:

45 Minutes

TYPE OF ACTIVITY:

Teacher Demonstration
or Student Activity

TEACHING STRATEGY:

Guided Discovery

CONCEPTS:

Parabolic Reflector
Radio Waves
Directionality of
Radio Waves

SKILLS:

Observation
Modeling
Interpreting Data

RESOURCES:

BK - A.4;D.1,3
FM - 32,39

Now, (1) ask a student to rotate the radio until the best reception possible comes from one of the weak stations.

(2) Have the student hold the umbrella behind the radio with the aluminum foil facing the incoming waves as shown:



(3.) Slowly move the umbrella closer to or farther from the radio until the position that best improves the strength of the radio waves is found.

With the class, repeat steps 1, 2 and 3 above for the other weak stations and put a check mark next to each station whose radio waves are strengthened by the radio telescope.

Finally, place the radio telescope model between the radio and the incoming waves as shown:



Notice what happens to the radio waves with the "telescope" in this position.

Discuss with the class such questions as:

A. Where did the radio waves that the radio received come from: (the station)

B. Where do radio waves that are picked up by actual radio telescopes come from? (Sun, other stars, quasars,



pulsars)

C. What happened when the umbrella was put between the radio and the transmitting station? (Blocked the waves)

D. What is the function of the aluminum foil in this activity? (Acts as reflector for the waves.)

E. Why did the radio waves strengthen when they were reflected by the umbrella? (Concentrated all the waves captured by the parabolic arc and reflected them to one point.)

F. Why do we listen to the sounds from space? (To "see" what stars are doing, to get beyond what visible light telescopes can see, to find new stars; to listen for the sounds of extraterrestrial life in space.)

G. If there are any extraterrestrials out there, what message might they be trying to get through to us?

Extension: (1) Discuss the possibility of extraterrestrial life with the students and, just for fun, assume that the principles of bio-chemistry remain constant in the universe. What sorts of creatures might have evolved out there on other planets? Think about the environment of the planet and design a life form that "fits" the environment of choice. (Mars, for example, might have a very large, red, toad-like creature with enormous webbed feet for use as sand shoes, with very strong hind legs for magnificent leaps in the reduced gravity and huge deployable wings that he uses, along with those webbed feet, for sand surfing when the spirit moves him. He probably lives for frozen CO₂!)

Have students choose a planet or star that we know something about and draw a form of life they think would be appropriate for it.

(2) Find information on the radio transmitter ET made in the movie. How is this similar to the radio telescope model made by the students?

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

Several periods

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:Open Discovery
Guided DiscoveryCONCEPTS:Solar System
Planet
EnvironmentSKILLS:Reading for
Information
Presenting DataRESOURCES:BK - A.3;C;D.4a,5c,d
FM - 37,38

Objectives: To provide students with an understanding of some of the similarities and differences between the planets; to provide an understanding of the environmental conditions of the planets.

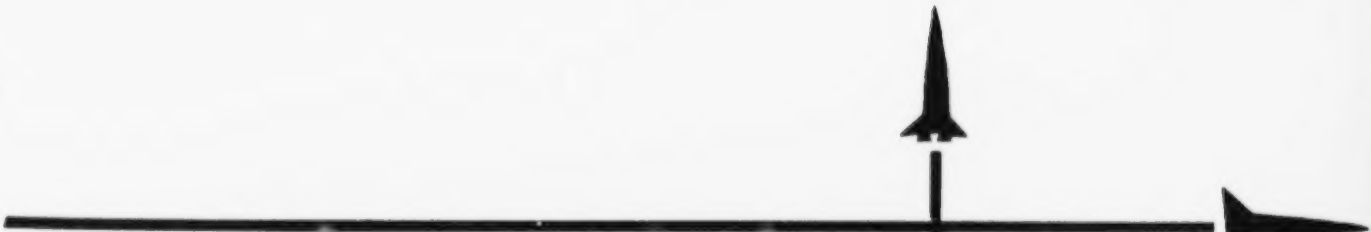
Materials: Books, pamphlets, etc., on the various planets; discussion sheet.

Teacher Background Information: The ancient astronomers observed points of light in the sky which appeared to wander among the stars. They called these objects planets, which means "wanderers," and named them after great mythological deities - Jupiter, king of the Roman gods; Mars, the Roman god of war; Mercury, messenger of the gods; Venus, the Roman god of love and beauty; and Saturn, father of Jupiter and god of agriculture.

In the past 25 years of the Space Age, knowledge about the solar system has advanced farther than in all the previous centuries since civilization began. Revolutionary views of the planets have been provided, mostly by NASA Mariner, Pioneer and Viking spacecraft but also by NASA-supported telescopic, balloon, sounding rockets and high altitude aircraft studies.

Mercury has been seen by Mariner 10 spacecraft and sharp pictures of about half of the planet's surface have been provided. The Pioneer Venus mission dropped five probes into the Venusian atmosphere and put an orbiter around the planet. Earth has been viewed from space in a number of ways including weather satellites, Landsat and, of course, by our astronauts standing on the Moon. Viking spacecraft have brought information of Mars and raised as many questions as they have answered.

The outer planets are for the most part still shrouded in mystery but NASA's Pioneer Saturn spacecraft gave the world its first close look at Saturn in September, 1979. Since then, we had to rewrite the books when Voyagers 1 and 2 provided close-up studies of both Saturn and Jupiter. Voyager is expected to send data from Uranus in 1986, from Neptune in 1989 and, by the turn of the century, we should have some close-up information on the planet Pluto - a planet only discovered a little over 50 years ago orbiting over 2½ billion miles from Earth.



These are exciting times for astronomers and your students can begin a look at this solar system of ours at a time when news is abundant and ever changing.

Procedure: 1. Write the word PLANET on the chalkboard and ask what the word means. Arrive at a workable and accurate definition and write it on the board.

2. Ask what the nine planets of our solar system are called. Write them on the board.

3. Ask what solar system means. Clarify its meaning with students and write it on the board.

4. Have the students put the planets in relative order from the Sun and talk about the fact that Neptune and Pluto are reversed from their usual order 'right now.

As the class discusses the planets in the solar system, work through the definitions of at least these words before they proceed: planet, star, solar system, galaxy and universe.

Write any questions that come up during the discussion on the chalkboard and let students know they will be finding information on some of these questions.

5. Divide the class into nine groups and assign them a specific planet. They are to search for information on the environmental conditions of their planets. They should look for such things as:

1. the atmosphere of the planet
2. any rocks or minerals the planet contains
3. any forms of life
4. the range of temperatures
5. how the planet might have originated
6. when astronomers first found it
7. its distance from the Sun and from the Earth
8. how the planet compares to other planets, especially to the Earth
9. any moons or rings it may have
10. what spacecraft or techniques were used to gather data about the planet

Once the data is gathered, each group is responsible for providing a detailed booklet complete with pictures or diagrams for the other groups to read. This is a big responsibility so information must be accurate and

up-to-date. Make sure your students know that this writing is to be read and will be accepted as factually and honestly presented.

After the class has had the opportunity to read all the booklets, hold a general class discussion and discuss some of the questions on the activity sheet found on the following page.

Extension: Have students write a travelogue script from the point of view of the planets; that is, in the first-person, i.e., "I am Mercury. I . . .etc.) Get slides from NASA on the various planets. Find music appropriate for a planetary travelogue and put together a presentation for other classes to see and hear.



Jupiter looms ahead of the Voyager 1 spacecraft. The Great Red Spot is visible at the lower left. Slightly above the feature, and to the right, is the volcanically active moon Io.

A TRIP TO THE PLANETS

Questions for Discussion

1. What are some of the similarities between the inner planets?
2. What are some of the differences?
3. Why do ground telescope observers have difficulty in studying Mercury?
4. Why is life on Mercury impossible?
5. Describe Venus' cloud cover and atmosphere.
6. Describe the planetary theory regarding a planet's loss of the original gases in its atmosphere.
7. Which of the four inner planets apparently has no magnetic field?
8. What do you think would happen to Earth if all of the carbon dioxide locked up in its rocks suddenly escaped into its atmosphere? What could cause this cataclysm?
9. There are three hypotheses on how the inner planets acquired potentially volatile materials: primary atmosphere, grain accretion, and external source. Describe them and explain why you think a particular one is the most likely.
10. Why are conditions on Earth favorable to life?
11. Why has Earth's atmosphere caused the premature fall of the Skylab space station?
12. Give and explain your theory of the Moon's origin?
13. Discuss why you think or don't believe that there is or was life on Mars.
14. Why do geologists enjoy studying Mars?
15. Why does the Mars moon Phobos interest scientists?
16. How does the nature of the solar system change beyond Mars?
17. How many satellites has Saturn?
18. What are the most popular hypotheses concerning the origin of Saturn's rings?
19. How does Saturn resemble Jupiter? Uranus? Neptune?
20. What is the solar system's largest satellite? It's smallest? It's most (environmentally) like the Earth? It's most likely to have resources the Earth can recover and use?

Objectives: To simulate the cratering process found on the Moon and planets; to investigate the effects of the angle of the Sun on the viability of craters in photographs; to demonstrate the aging process of craters on the Moon.

Materials: Five petri dishes; fine mesh sand; simulated raindrop maker (fine mesh nylon stocking stretched on an embroidery hoop.); water sprayer (spray bottle type); container for damp sand; old newspapers for table top; Polaroid camera and film; stop watch.

Teacher Background Information: This experiment is designed to create craters in dry sand by placing filled petri dishes in a light rain or by using simulated raindrops over the dishes. The raindrop craters represent a relatively random process in which each drop has about the same chance of impacting in a given area as in any other area. Given enough time, several impacts may occur by chance in the same spot causing a large crater which may be mistaken for a crater formed by a single event. Careful observation of large craters may reveal that they were in fact formed by several "hits" in the same area.

As more and more craters are formed, they begin to overlap and destroy one another. The craters will start out small and theoretically "saturate" an area with craters of about the same size. Slowly, as meteorites hit the same areas more than once, the crater size in an area will grow. Generally, the larger the craters in an area the older the area is thought to be.

Procedure: 1. Fill the petri dishes with dry sand and smooth the tops off.

2. Place a dish in a light rain for about 5 seconds. This should produce only a few craters. How do the craters compare in size? Are they clustered or single? Do they overlap?

3. Place a second dish in the rain for about 30 seconds. How do these dishes compare?

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Small

TIME:

60 minutes

TYPE OF ACTIVITY:

Student Investigation

TEACHING STRATEGY:

Expository
Guided Discovery

CONCEPTS:

Cratering
Interpreting Data
Modeling

SKILLS:

Modeling
Experimenting
Interpreting Data

RESOURCES:

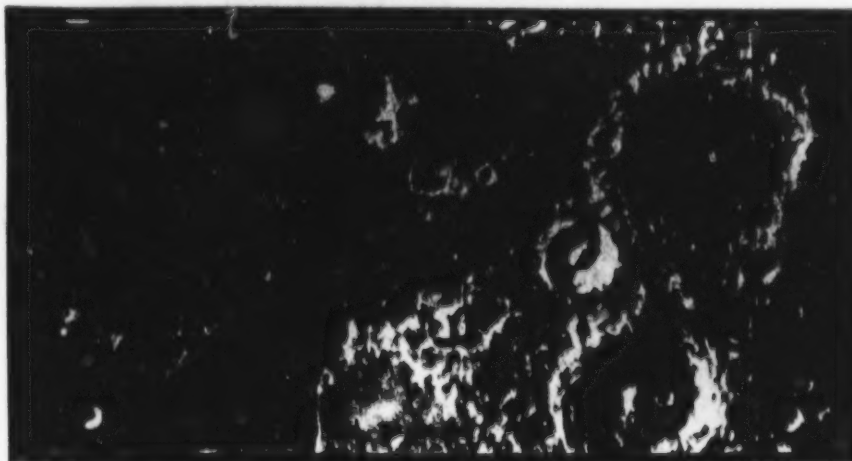
BK - A.5b;D.5c3
FM - 49,51,52,60

4. Drop a marble or steel bearing into another dish or make a crater with your finger. Place this dish in the rain for about 30 seconds. What happened to the large crater you made?

5. Form craters in two more dishes with the bearings or your finger. Place one dish in the rain for two minutes and the other for about four minutes. What happened to the large craters? Are there any tiny craters in the dishes? These can be formed by the "ejecta" from the other craters. Are there more of the tiny craters in the dish left for 30 seconds? in the dish for 5 seconds?

Extensions: Turn off all the lights in the room and shine a light on the dishes from different angles. Compare the number of craters you see with the light at several angles. Try photographing the dishes in each of the lighting situations. The identification of craters and other features on the Moon depends greatly on the angle of illumination. This is easily seen by looking at the moon at different stages through a telescope. The tiny details are best seen at the sunset line where the shadows are the greatest. This does exaggerate the features however and may lead to false conclusions about the relative height of the ridges. Compare the photos of your dishes with the real thing.

.....adapted from material available from the NASA Educational Programs Division.



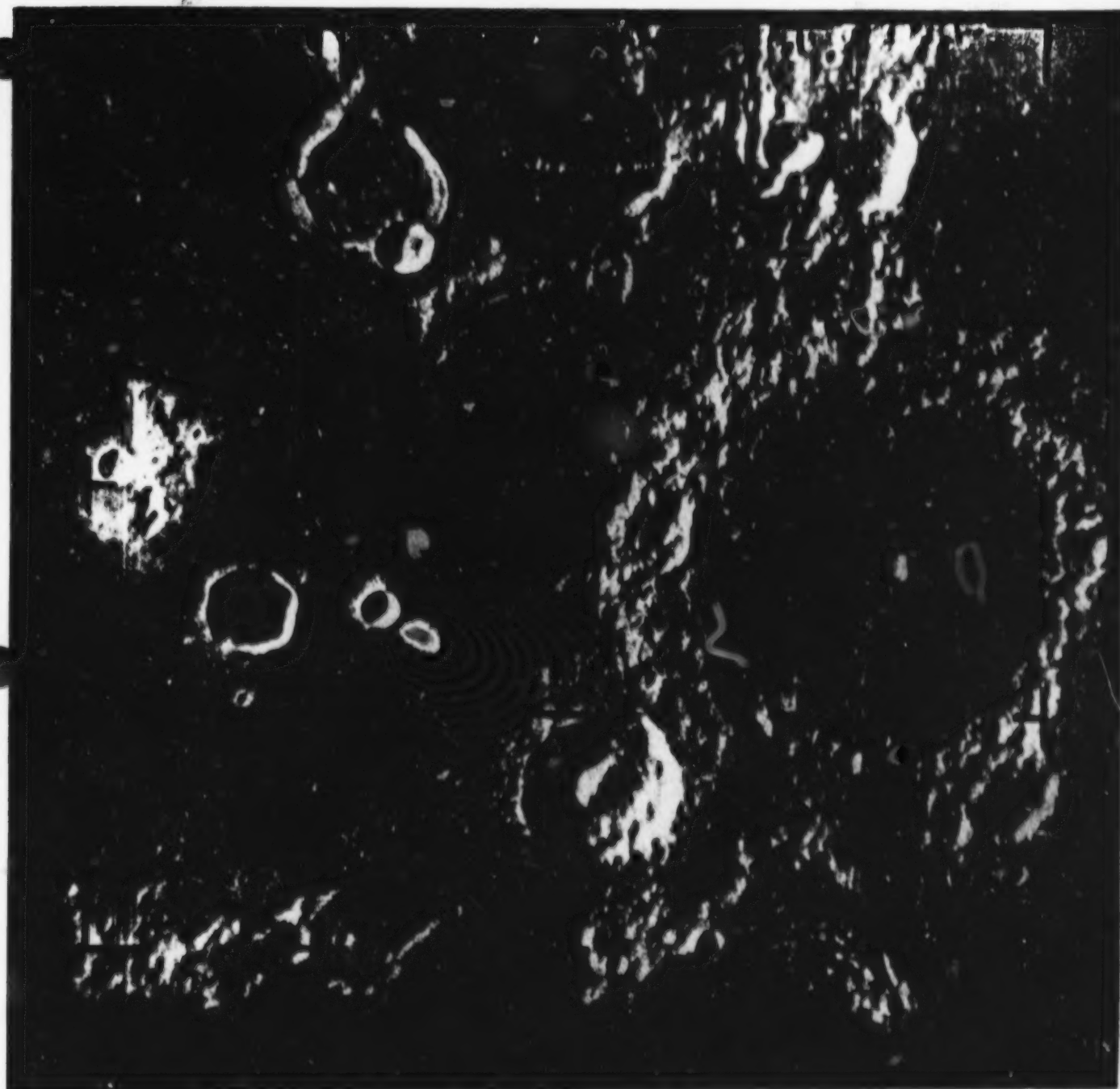


PLATE E

(RANGER IX IMAGE)



PLATE K

(RANGER IX IMAGE)

218

Objectives: To provide the opportunity to calculate distances from Earth to a "nearby" star; to understand one of the difficulties about traveling in space is the time it takes to get somewhere.

Materials: Activity sheet provided.

Teacher Background Information: One of the major problems with space travel is the amount of time it takes to cover the vast distances to even our closest neighbors. This short exercise gives the students some feeling about those distances and the time to cover them. Though this is primarily a math activity, the concept is essential to the understanding of many of the other problems associated with space travel.

Procedure: Before handing out the activity sheet, talk with the students about some of the more fanciful space programs on TV or at the movies. Travel between planets and stars on some of these programs seems rather easy but, once the vast distances are truly comprehended, the difficulty of getting from one planet to another, using present technology, becomes apparent. Ask the students if they know how far it is to the nearest stars or to the recently discovered solar systems. Get some mileage estimates and write them on the board. Then put up the following chart:

<u>STAR NAME</u>	<u>DISTANCE IN LIGHT YEARS</u>
Proxima Centauri	4.3
Barnard's Star	6.0
Wolf 359	8.1
Lal 21185	8.2
Sirius	8.7
UV Cet	9.0
Ross 154	9.3
Ross 248	10.3
Eri	10.8
Ross 128	11.1
61 Cyg	11.2
Procyon	11.3

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Individual

TIME:
60 minutes

TYPE OF ACTIVITY:
Student Activity
Discussion

TEACHING STRATEGY:
Guided Discovery
Discussion

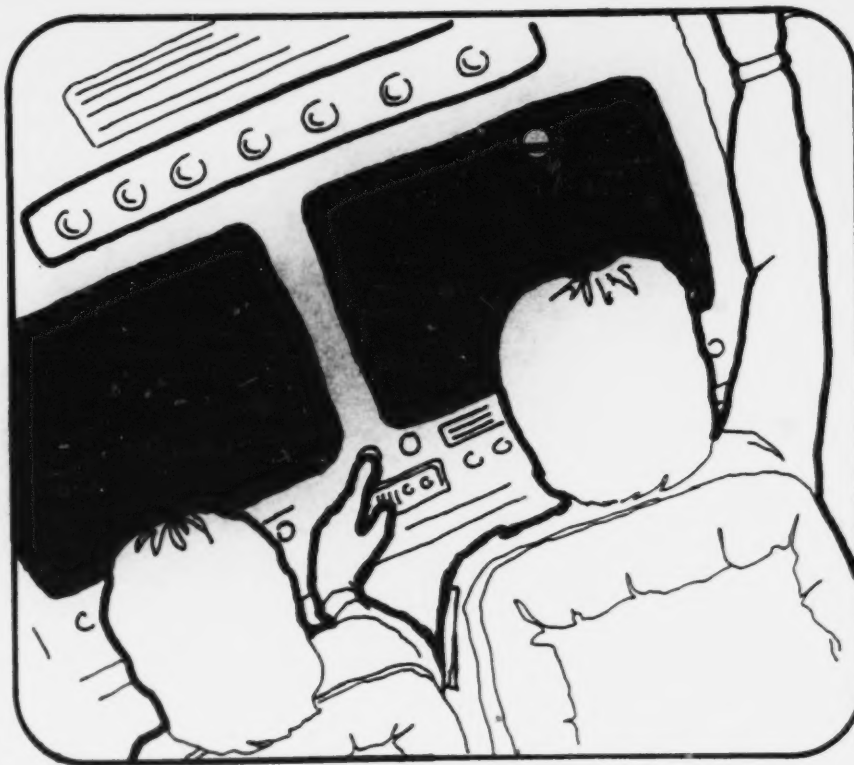
CONCEPTS:
Light Year
Relative Distance
Space Travel

SKILLS:
Reading and
Interpreting Data
Computation

RESOURCES:
BK - A.2c;C;D
FM - 32

Ask your students to select a star for use in the activity and hand out the activity sheets to each of them. Talk about light years with them and make sure each has computed the first question correctly. Do a second question with them using a star they picked. Check again to be sure they understand how to compute correctly. Let them finish the rest of the problems on their own.

Extensions: Have your students look up the distance to other stars they may have heard of or to the Vega system where a solar system was recently discovered. Have them compute the distance and perhaps the length of time it would take to travel there at some portion of the speed of light. If it were possible to travel at the speed of light, how long would it take? (See lesson 92 on page 229, "It's All Relative," of the K-6 "Come Fly With Me" science book for more ideas)



ACTIVITY SHEET
FOR
HOW LONG 'TIL WE GET THERE?

Distance to a star is expressed in units called Light Years. A light year is the distance light can travel in one year. At 186,000 miles per second (light speed) how far would light travel in a year? _____

Pick a star from the chart your teacher has placed on the board. Your star is called _____. It is _____ light years away. Converting this into miles, your star is _____ miles away. Now let us consider our present level of technology, as well as the possibility of a major breakthrough in our propulsion systems.

Because of the large numbers involved, we will stick to round numbers. It is not an exact number that is important here, it is the concept of time required that is important.

To escape the Earth, you need to exceed the speed of 25,000 miles per hour. We have achieved this speed on numerous probes to the inner and outer planets. At the speed of 25,000 miles per hour, how long would it take you to reach the moon, a distance of about 225,000 miles? _____.

When we first went to Jupiter, we reached a speed of 32,000 miles per hour. At that speed, how long would it take you to reach the moon? _____.

At that same speed, how long would it take you to cross the United States? Consider the distance about 4000 miles. Your answer will be part of an hour. Convert this to minutes. _____.

Given the speed of 50,000 miles per hour (the Pioneer on passing Jupiter achieved this speed), how long would it take to reach your star? _____

Now let's take a step into the future and ride a space craft which can travel about 1,000,000 miles per hour. At that speed you could reach the moon in about 15 minutes and cross the United States in about 16 seconds. How long would it take you to reach your star? Give your answer in hours, days and, finally, in years. _____

Objectives: To understand the structure of a comet; to understand comet orbits and periods.

Materials: Books, pamphlets, etc., on comets.

Teacher Background Information: In 582 AD, Gregory of Tours wrote the following:

"... there were rains, lightnings and great thunderclaps in the month of January. Trees blossomed; the comet appeared in such a way that round about it there was a great blackness; it shone through the dark as if set in a cavity, glittering and spreading abroad its hair... And on the holy day of Easter, in the city of Soissons, men saw the heavens aflame, in such wise that there appeared two fires, the one greater, the other less. But after the space of two hours they were joined together, making a great beacon-light before they vanished away. In the territory of Paris there rained real blood from the clouds, falling upon the garments of many men, who were stained and spotted that they stripped themselves of their own clothing in horror."

By the late 1600's, due in large measure to astronomers like Tycho Brahe and Sir Edmund Halley, accounts of such destruction following in the wake of a comet sighting had become a great deal rarer. However, enthusiasm for comets has not waned (witness the recent movie "Comet" which brought celluloid disaster to the greater part of Arizona). The return of Halley's Comet in 1985 and 1986, provides an even greater interest in what comets are all about.

Because of the return visit, several European countries, the Soviet Union and Japan designed spacecraft to study Halley's comet and, though the U.S. plan to design a craft specifically to study Halley was rejected, a satellite already in orbit was deflected to get some closer pictures of the comet as it passes by.

Procedure: 1. Write the word COMET on the board and read the account written in 582 AD by Gregory of Tours. Discuss the passage and ask the students to relate what information they have on comets.

2. As the students bring up information

SUBJECT:

Science

GRADE:

7,8,9

GROUP SIZE:

Large

TIME:

60 minutes

TYPE OF ACTIVITY:

Discussion

Student Investigation

TEACHING STRATEGY:

Open Discovery

Guided Discovery

CONCEPTS:

Comet

Orbit

Period

SKILLS:

Reading for

Information

Interpreting Data

RESOURCES:

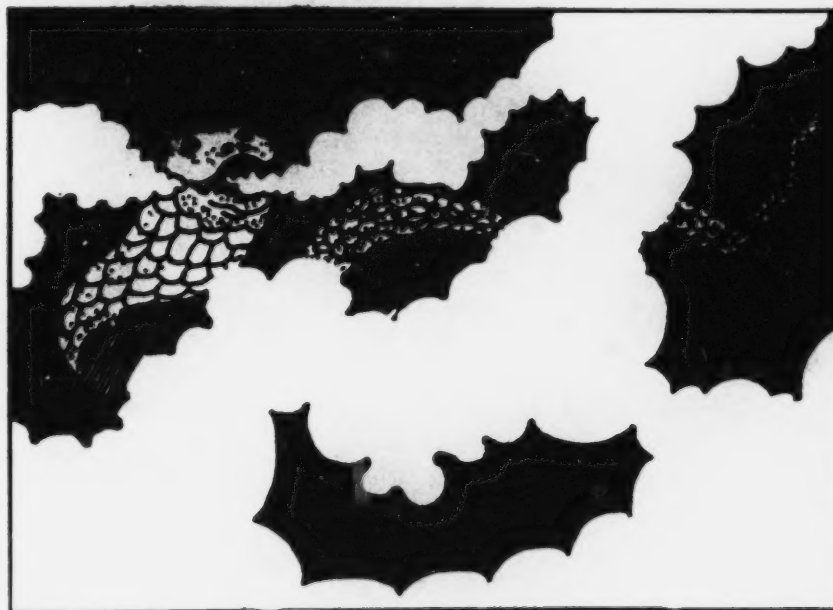
BK - D.5e

FM - 35,36,37,38

that is unclear or contradictory, work with them to formulate questions for them to find information on. Some of the likely questions might be:

Just what are comets?
What are they made of?
Where do they come from?
How come some show up in regular periods of time?
Why are they called comets?
What comet(s) might we be able to see during the next few years?
How are comets named?
Why do they have a tail?
What happens when one hits the Earth?
What are the chances of that happening?
Should we be worried about that, T00?!

Once the students have generated questions, ask how they think they might find information that would help them to answer some of the questions. Talk about the possibilities - where to look, what to read, who to write or talk to. Divide the questions among the students and ask them to do some searching and to report back to the class in a way that is as exciting as watching a comet streak across the sky.



Data from "Comets,"
Center for Astrophysics,
Harvard Col. Observatory,
Cambridge, MA

WHAT THE ROCKS TELL US

Objectives: To have students use various methods to identify rocks; to relate the study of Earth rocks to Moon rocks.

Materials: Unknown rocks (p.222), numbered; dilute hydrochloric acid; knife blade or nail; hand lens; colored pens or crayons, activity sheet; rock identification key; Moon Rocks (See end of activity for information).

Teacher Background Information: Rocks, of course, cannot literally speak. But they do contain interesting stories and they can reveal their stories through the scientist's experienced eyes and sophisticated instruments. The shape, size, arrangement and composition of the individual grains and crystals in a rock tell about the history of the rock. The rock's internal "radioactive clock" tells us its age. Tiny tracks may even tell the radiation history of the Sun during the last 100,000 years.

In some aspects, the appearance of lunar rocks resembles that of Earth rocks. The minerals are the same. The grain sizes are comparable. The shapes are familiar. But in other aspects, their appearance differs significantly. For example, the Moon rock's surface is pitted with tiny craters, and the rocks are extraordinarily fresh.

In order to compare Moon rocks with Earth rocks, students will need some background in identifying various rocks. The activity sheet should help them to do that.

Procedure: Provide activity sheets for each student or small group of 2 - 3. Provide a copy of a rock identification key to each student or group or have a couple at hand in a learning center where the activity can be completed.

Explain that the activity sheet is in three parts:

Part A can be completed by using the various identification methods the students should be familiar with (Acid, Streak, Hardness, Specific Gravity Tests).

Part B can be completed using their own observations and/or other sources such as their textbook or books on rocks.

SUBJECT:
Science

GRADE:
7,8,9

GROUP SIZE:
Small

TIME:
2-45 minute periods

TYPE OF ACTIVITY:
Student Investigation
Teacher Demo

TEACHING STRATEGY:
Expository
Guided Discovery

CONCEPTS:
Rock Identification
Moon Rocks

SKILLS:
Following Directions
Collecting and
Interpreting Data

RESOURCES:
BK - A.5b;C.2b;D.5c3
FM - 49,52,53

Part C will require that they do some research, use their observations and experiences and think very carefully about what they have read and observed.

Finally, provide the students with the set of Moon Rocks obtained from NASA and complete some of the activities provided.

To obtain Moon Rocks requires that a teacher be certified by NASA at a workshop where trained personnel provide insight into how to use the Moon Rocks most effectively in the classroom. Security information is also provided at that time. Contact the NASA Teacher Resource Center for your area (See list in Appendix) to arrange a workshop.



WHAT THE ROCKS TELL US

ACTIVITY SHEET

PART A

1. Divide a sheet of paper into five columns as shown.
2. At the head of the first column write UNKNOWN SAMPLE. Title the remaining columns as follows: ROCK NAME, ROCK FAMILY, DRAWING, OBSERVATIONS.
3. Write the number of each of the rock samples down the left side of the page, as shown.
4. Use the key your teacher provides to identify the unknown rocks. Indicate whether the sample belongs to the igneous, sedimentary or metamorphic family. Allow enough space to draw and color each rock in the fourth column.
5. Record anything unusual you observe in the OBSERVATIONS column.

UNKNOWN SAMPLE	ROCK NAME	ROCK FAMILY	DRAWING	OBSERVATIONS
1				
2				
3				
4				
5				

IGNEOUS	SEDIMENTARY	METAMORPHIC

PART B

Sometimes it is very difficult to tell whether a rock is igneous, sedimentary or metamorphic. Make a table, such as the one shown, and list as many of the outstanding features you can think of for each family of rocks. You may use your own observations or check with other sources such as books on rocks or a science textbook that covers this area.

PART C

Answer the following questions:

1. What might be one reason two samples of the same rock type sometimes look different?
2. Why do you suppose most of the rocks we see at the surface of the Earth are in the sedimentary family?
3. What may have caused the bands of color to form in gneiss? In what kind of rock are layers usually found? How is gneiss different from that kind of rock?

ROCK IDENTIFICATION KEY

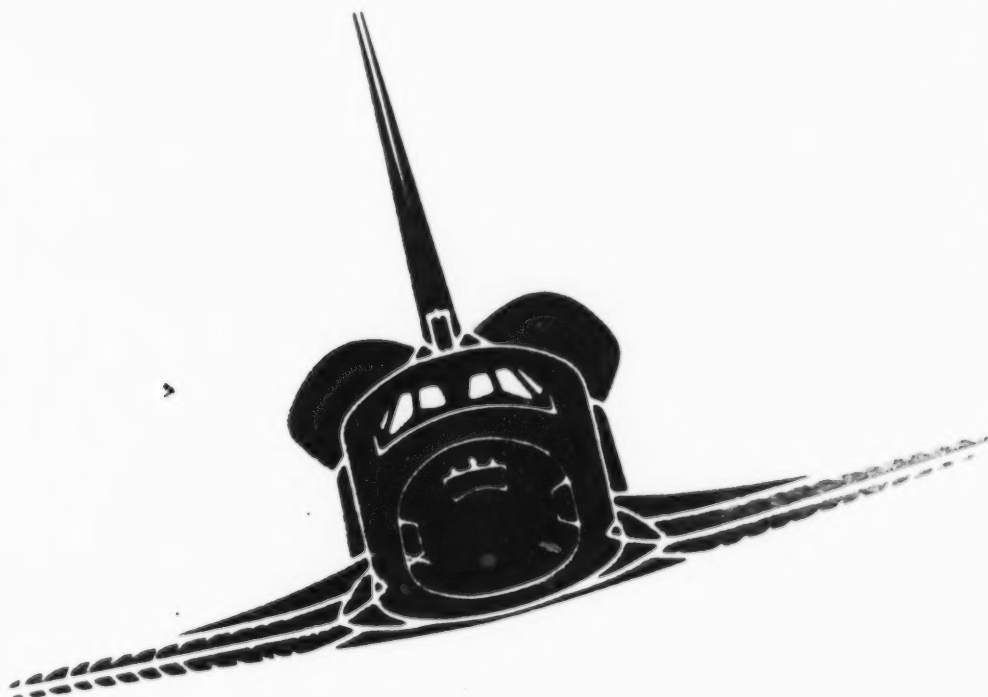
Name of rock	Description
1. Basalt	dark gray to black; crystals not usually visible; heavier than #10
2. Bituminous	soft, shiny coal; cannot be scratched by fingernail
3. Conglomerate	cemented pebbles
4. Gabbro	large, dark, interlocking crystals
5. Gneiss	bands of color that may or may not be bent; often visible crystals
6. Granite	interlocking pink, gray, and dark crystals
7. Limestone	may contain tiny shells or interlocking crystals; usually light-colored; fizzes in acid
8. Marble	color varies, may appear very crystalline; fizzes in acid
9. Obsidian	dark; glassy-looking; fractures with curved surface
10. Pumice	lightweight and holey; looks like a cinder; comes from volcanoes
11. Rhyolite	pinkish-tan; crystals not visible without magnification
12. Sandstone	cemented sand grains; color may vary
13. Schist	may have long stretched crystals: may shimmer or look flaky
14. Shale	color varies but usually dark; smells musty when it is moistened
15. Slate	looks like a piece of blackboard; harder than #14



**NSTA-NASA Space Shuttle
Student Involvement Program**

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"Now voyager, sail forth ... to seek and find..."
Walt Whitman

**A NOTE TO TEACHERS ON THE
SPACE SHUTTLE STUDENT INVOLVEMENT PROGRAM**

One of the ways to motivate students in science is for your pupils to know that the concepts they are struggling to learn can be applied in meaningful ways. Of the various ways to do this, one of the most interesting and enjoyable applications is the Space Shuttle Student Involvement Program which provides an opportunity for students, enrolled in grades 9 through 12, to propose experiments suitable for possible flight aboard the Space Shuttle and, where appropriate, for performance by the astronauts. The National Science Teachers Association and the National Aeronautics and Space Administration have joined in conducting and sponsoring the program.

The purpose of the SSIP is to stimulate interest in science and technology by directly involving students in a space research program. Students may propose an experiment suitable for flight aboard the Shuttle by submitting their proposal to the SSIP director of their region. Every student and his/her advisor who enters SSIP will receive a Certificate of Participation. Up to twenty students in each of the ten geographic regions will be selected as Regional Winners. These Regional Winners, their teachers and their schools receive special Awards of Recognition.

All Regional Winners and their teacher-advisors are awarded an expense-paid trip to a special Space Shuttle Symposium held at a NASA research center. During the symposium, winners have the opportunity to talk about their proposals with NASA and other space scientists.

Finally, up to ten National Winners are selected from the Regional Winners. In addition to their regional awards, National Winners and their teacher-advisors are invited to a National Space Shuttle Symposium, expenses paid, where they receive awards for themselves and their schools. All proposals will be considered for selection by NASA for possible flight on a future Space Shuttle mission. A list of National Winners, their topics and a synopsis of their projects can be found at the end of this Teacher Note.

A new contest is announced at the beginning of each new school year and national winners are selected the following spring. To receive information on the SSIP, you can write to NASA or the NSTA. You will receive the Student Guide and Rule Brochure, an entry form, complete directions for writing a proposal and information on recent winners' projects. Write to the NASA Research Center in your region (See Appendix) or write to:

Shuttle Student Involvement Project
National Science Teachers Association
1742 Connecticut Ave., N.W.
Washington, D.C.
20009

Once you have sent for the information on the SSIP, choose several of the activities from the COME FLY WITH ME materials. (You may wish to take a look at the K - 6 COME FLY WITH ME materials, as well. Many of the upper level lessons, especially, can be modified and used at the Jr. High level. For students with less than a minimum background in aerospace, the activities from the upper elementary level can provide valuable information.) In addition to the lessons you choose from Life, Physical or Earth Science sections of this curriculum guide, there are several activities, a game and Shuttle information in this section. These activities are intended to motivate students to learn about the Shuttle and of the work that goes on there rather than to focus on a particular science concept.

As your students do some of the concept and motivating activities, explain that they can use the concepts they learn to become part of the Space Shuttle Student Involvement Program and possibly have an experiment of their own performed aboard a Shuttle flight. Even if that doesn't happen, the students will have engaged in some very meaningful science. They will also have the opportunity to try again in the 10th, 11th or 12th grade.

As the students work through the various activities from the COME FLY WITH ME materials, have them keep in mind that the culminating activity will be the experiment for the Space Shuttle so they should be thinking of the ramifications of their activities with regard to that, as well. As students consider Space Shuttle proposals, it might be helpful if they know what the required elements of the proposal are. The following is an indication of what the judges look for and the criteria they use.

THE ENTRY

An entry should be a typed proposal of a project to be done: experiments, demonstrations, or, perhaps, activities to be performed by the astronauts in the course of the Space Shuttle missions. It is not intended that an experiment be constructed or performed by the student. It is imperative that proposals deal with concepts which use one or more of the unique features of the Space Shuttle such as a microgravity environment, operation above the Earth's atmosphere, or a broad view of the Earth's surface. The proposal text should not exceed 1000 words.

Experiments can be proposed from such areas as Behavioral Science, Social Sciences, Environmental Sciences, Mathematics, etc.

REQUIRED ELEMENTS

1. **Scientific Validity** (10 points)

The proposal concept, means of execution, and analysis should be consistent with currently known and generally accepted principles in pure and applied sciences.

2. **Suitability** (10 points)

The student should demonstrate the suitability of the proposal as a science activity for the Space Shuttle Program.

3. Creativity and Originality (10 points)

The student should develop a proposal which states a concept or process or an equipment design which demonstrates originality, or the student should design adaptations to the equipment or a process used in previous space research for analysis to show originality.

4. Organization and Clarity (5 points)

The student should describe the proposed experiment in space according to the proposal elements described.

Definition of the elements of an acceptable proposal are provided below. Teacher-advisors should use the guidelines of these elements as they review the proposals of students.

A. TITLE - This must briefly but accurately describe the proposed experiment.

B. ABSTRACT - The abstract must be a concise general statement that describes the problem and how the student proposes to investigate the problem. The purpose of the abstract is to make the idea so interesting that people will want to read the entire paper. It should be 50-75 words (no longer). The abstract is NOT included in the 1000 word limit. This checklist can be used to evaluate the abstract:

1. Problem is described.
2. Proposed method(s) are described.
3. All variables are described.
4. Materials are described.
5. Data-gathering procedures are described.
6. Data-analysis procedures are described.

C. PROBLEM - Clear concise statements describing the problem should introduce the ideas and objectives to a reader of the proposal. Exactly what the experiment is attempting to discover should be stated. There should be a list of hypothesis(es) of the proposed experiment. An experiment is defined as the test of the hypothesis under controlled conditions. The experiment really is the way by which an answer to the problem is obtained. In other words, the problem is a question; the objectives are to answer the question.

D. MATERIALS - Materials listed should incorporate everything that is essential to perform the experiment. Dimensions, details, and properties of any equipment, supplies, or other materials proposed should be given. Drawings of hardware (equipment) may be attached to the proposal. These need not be precise engineering drawings; a rough conceptual sketch or other kind of illustration will do. However, all illustrations must be reproducible as judges will need to make copies.

E. PROCEDURES - To describe the proposed experiment, the student should list the procedures planned. The steps in chronological order, should be listed.

The variables in the proposed experiment should be described. There are two types of variables:

Independent variable. The property that changes or can be changed and is believed to affect the dependent variable.

Dependent variable. The property believed to be affected by a change in the independent variable.

F. **DATA ANALYSIS** - A description of how the data collected after the experiment has been completed will be organized and analyzed.

G. **REFERENCE BIBLIOGRAPHY** - A bibliography is a list of all the books, articles, or other documents used in developing the proposal. These should be listed, in alphabetical order by author's last name, and numbered in sequence. The bibliography is the last section of the proposal. For proper format, consult a standard reference book such as the MLA Style Sheet.

Proposals, plus a completed official entry form (found in the Student Guide) are mailed to the director of your region. The names and addresses of all directors are listed in the Student Guide. Entries are NOT mailed to NASA or the National Science Teachers Association.

Proposals must be received by the Regional Director before a specified date usually somewhere around February 1. For specific dates, write for the Student Guide and the Rule Brochure each year before school starts in the fall.



NATIONAL WINNERS

SSIP 1980-81

"Biofeedback."

Wendy A. Angelo

Poughkeepsie, NY

Arlington High School (South Campus).

Jan L. Stoutenburgh, Teacher-Advisor.

STS-8, Scheduled August, 1983

U.S. Air Force School of Aerospace

Medicine, San Antonio, TX.

A proposal to test the usefulness of biofeedback training to induce more restful sleep of crew members during Space Shuttle flights. The project calls for psychologists trained in biofeedback techniques to provide a month of training, approximately 30 min./day, for half the crew prior to flight; suggested equipment includes EMG and metronome.

During the flight the biofeedback trained crew members would for a few minutes prior to their sleep period use feedback techniques to induce slumber. Following the flight, the log books and medical records of the trained and untrained crew members would be compared. Also compared could be the results of this flight to those of previous flights.

"The Growth of Porifera in Zero Gravity."

Aaron K. Gillette

Winter Haven, FL

Winter Haven Senior High School

Maryclaire Maltese, Teacher-Advisor

STS-5, November, 1982

Martin Marietta Aerospace, Orlando Division

A proposal to study the effect of zero-gravity upon *Microciona prolifera*, commonly known as the sponge, in relation to its reaggregation of structure and shape and spicule formation following dissociation of the sponge.

The equipment proposed is a Shuttle-locker-size aquarium, divided into a major and minor aquarium. The major aquarium where the sponge will be dissociated comprises (a) a dissociation cubicle, with a unit designed to squeeze the sponge through a wire mesh; (b) a time-lapse camera; (c) a water filter; (d) a CO_2/O_2 exchange system; (e) an oxygenator; (f) a small, low-powered refrigeration unit; (g) a battery to provide power; (h) a control panel; and (i) a supply tube for nutrients. The minor aquarium, serving as a control, will be comparable, except that the sponges will not be dissociated. On return to Earth, the film will be developed and examined. Marine invertebrate zoologists will also examine the sponges to determine

the results of the reaggregation process.

"Simulated Atmosphere on a Weightless Sphere."

Pritchett A. Harris

Ambler, PA

Upper Dublin High School

John F. Joniec, Teacher-Advisor

Phase I - Rockwell International

A proposal for developing a method for data recording of liquid flow over the surface of a gravity-free sphere. The data obtained and the method could be applied to planetary weather analysis.

The project calls for a grid-marked, stainless steel sphere, that could be made geographically correct in terms of the planet to be analyzed: mountains simulated, areas painted to absorb or reflect heat, an internal or external heat source the inclination of which could be changed to represent different seasons. Necessary will be a battery-powered drive motor with Teflon-coated shaft to rotate the sphere; a gas-pressurized forced-delivery system for spreading an oil coating and injecting three dyes of different densities and colors; cameras positioned around the sphere and at the pole opposite the drive shaft.

"The Effect of Prolonged Space Travel on Levels of Trivalent Chromium in the Body."

Karla R. Hauersperger

Charlotte, NC

East Mecklenburgh High School

Wilma M. Collins, Teacher-Advisor

STS-4, June, 1982

Explorers Club, New York, NY

A proposal to investigate the effect of prolonged space travel on carbohydrate metabolism by altering the bioavailability of trivalent chromium in the body. A clue to the study's significance is the poor absorption of trivalent chromium by long-term, bed-ridden patients, confinement to bed being similar to weightlessness.

Methods and resources: nutritionists prepare a six-day menu cycle with measurable amounts of chromium, 0.05-0.2 mg daily, to be consumed over 30 days. Samples include three sets of seven subjects each: Sample A, the mission crew; B, the sub-orbital crew; and C, members of ground management staff; each sample will comprise subjects comparable in age, (25-50), health (free of diabetes and chromium abnormality), and sex, male and female. Prior to beginning of the journey, each subject will undergo a

standard glucose tolerance test and a standard chromium test, the latter by atomic absorption spectrophotometry. After the 30-day period, each subject will be measured by standard clinical laboratory procedures; the only variable would be the weightlessness state occurring in space travel.

"The Formation of Crystal in a Weightless Environment."

Michelle A. Issel

Wallingford, CT

Mark T. Sheehan High School

Thomas J. Cigas, Teacher-Advisor

STS-5, November, 1982

United Technologies, Hamilton Standard, Windsor Locks, CT

This proposal concerns the formation of crystals in a weightless environment aboard the Space Shuttle.

Equipment and material considered necessary by the student include: a saturated sodium chloride solution in a cubic, clear, nonshattering container with an expandable lid; a Teflon-coated magnetic stirrer; a cross-shaped measuring device graduated in fractions of millimeters for horizontal and vertical measurement of crystals, a thermometer within the measuring device; a gray scale to determine clarity of crystals; a heat source that can be automatically turned off at a predetermined point; and a camera (possibly more than one) capable of time-lapsed photography with a built-in timer. Student recommends camera be programmed to record crystal growth from different angles in 5-minute intervals.

Also suggested is companion experiment to be conducted simultaneously using another crystal, such as alum.

"The Effects of Space Travel on Cytokinesis and Karyokinesis."

Dave D. Madura

Highland, IN

Highland Senior High School

Cheryl L. Mason, Teacher-Advisor

A proposal to discover what effects on cytokinesis and karyokinesis, if any, are caused by space travel. The student would use human lung fibroblast cells, periodically photographing samples of them in space flight and preserving others cryogenically.

Apparatus for the Shuttle flight and ground control would be identical. Equipment would include a container with a phase-contrast microscope which has a Rose Chamber attached to the stage; a camera with data back recorder, loaded with high contrast film (700 frames on 100 ft. roll) would be attached to the microscope, with a small fluorescent lamp to illuminate microscope. To provide cells with fresh growth media from a culture tube would be a perfusion pump. Disposal syringes with DMSO would be provided for insertion in culture tube, every 24 hours.

Temperature would be maintained by thermostat at 37° C. using a small incandescent bulb with fan and pump to circulate liquid through a copper heat radiator: container to be insulated with Styrofoam and aluminized mylar.

On landing, the cryogenically stored cells would be transferred to a liquid nitrogen freezer; the films would be closely inspected for anomalies and abnormalities. As these are found, the cryogenically stored cultures would be revived, cultured, and examined for more exact specification.

"Convection in Zero Gravity."

D. Scott Thomas

Johnstown, PA
Richland Senior High School
Wayne E. Lehman, Teacher-Advisor
STS-5, November, 1982
Morton/Thiokol, Brigham City, UT

A proposal for an experiment to study properties of convection in the near zero-g of Shuttle and the critical Marangoni number's dependence on viscosity, convection, cell size, depth of liquid, and surface deformation.

Equipment called for includes: four circular pans, each with slide-off cover, each pan 7 cm in diameter, to hold liquids 4 mm in depth, the bottom surface of the pan being hydrofelic, flat, and very wettable, the sides insulated from the bottom to avoid side-wall effects that plagued the Apollo experiments (liquids suggested are glycerol and Krytox 143 AZ oil); heat for three to be provided by uniform surface heaters; and for one to be provided by 240 spot heaters, 2 mm in diameter and 4 mm apart center to center, 3/100 watts each, and a heat sensor; a movie camera with heat-sensitive infrared film looking down on the pans, plus a movie camera with a microlens for attachment to side of each pan.

"The Effects of Weightlessness on Arthritis."

Daniel J. Weber

New York, NY
Hunter College High School
Francine Salzman, Teacher-Advisor
*STS-11
Pfizer, Inc., Groton, CT
General Dynamics/Convair Division, San Diego, CA

A proposal to record effects of weightlessness on adjuvant arthritis in laboratory rats. The student hypothesizes a relationship with human arthritis, based on relief arthritic patients receive from submersion in water because water's buoyancy reduces the force of gravity. He also believes there may be a relationship between relief from arthritis and the Skylab astronauts' loss of calcium and growth of approximately one inch in height.

The student proposes using eight small white Lewis rats (more if facilities are available); four would be flown on the

Shuttle; and four would remain on the ground as controls. His procedure calls for injecting four rats, i.e., two that fly and two that serve as controls, with Freund's complete adjuvant one month before the scheduled flight, and injecting the other four 12 days before flight. After the flight the rats will be autopsied by experienced researchers and the Shuttle-flown rats compared with the Earth-based for arthritic severity.

The proposal calls for the following equipment: a self-contained small-scale life support system comprising a box with a pressurized water system, a NASA Ames-developed food bar, a semi-permeable membrane for cabin air ventilation, and a battery-operated fan for air flow.

*Pending flight

SSIP 1981-82

"Testing Chemotaxis in Lumbricus Terrestris in the Absence of Gravity."

Sara H. Abazeid

Madison, WI
James Madison Memorial High School
Douglas Johnson, Teacher-Advisor

The purpose of this experiment is to determine the effects of carbon dioxide-oxygen gradient on chemotaxis in earthworms in the absence of gravity. The objective of the experiment is to see what causes worms to move up and down in the soil.

"A Test of an Electrostatic Confinement in Space."

William S. Akmentins

Appleton, WI
Appleton High School West
David McKay, Teacher-Advisor
*STS-15
Geledyne Brown, Huntsville, AL

This experiment will determine whether an object can successfully be confined to a certain area using electricity in zero-gravity, and if so, how much voltage it takes to keep the object in that area.

"Statoliths in Corn Root Caps."

Sean M. Amberg

Seward, NE
Seward High School
Donald Sackett, Teacher-Advisor
*STS-13
Martin Marietta Denver Aerospace

The effect of weightlessness on the formation of statoliths (gravity-sensing organs) in plants will be tested by exposing plants with capped and uncapped roots to spaceflight. The root caps of the flight and control plants will be examined postflight by electron microscope for statolith changes.

"The Effects of Weightlessness on Grain Formation and Strength in Metal."

Lloyd Bruce

St. Louis, MO
Summer High School
Vaughan Merrill, Teacher-Advisor
*STS-13
McDonnell Douglas Astronautic Company
St. Louis, MO

This experiment will heat a titanium alloy filament to near the melting point and observe the effect that microgravity has on crystal reorganization.

"Utilizing a Semi-Permeable Membrane to Direct Crystal Growth in Zero Gravity."

S. Richard Cavoli

Marlboro, NY
Marlboro Central High School
Annette M. Saturnelli, Teacher-Advisor
*STS-15
Union College, Schenectady, NY

This experiment will attempt to grow fine, rod-shaped lead iodide crystals in zero gravity. Such crystals have application to development of image-intensifying screens to be used as detectors of gamma and X-rays.

"Time Dilations Due to Motion and Gravity."

Steven D. Chang

Tustin, CA
Tustin High School
Ronald Bruce, Teacher-Advisor

The purpose of this experiment is to confirm quantitatively the simultaneous effects due to both Einstein's General and Special Relativity theories by comparing atomic clocks—one to be flown on the Shuttle and the other to remain on Earth.

"Cocoon-Spinning Behavior of Silkworms".

Todd J. Egan

San Jose, CA
Bellarmine College Preparatory
Sandra Capano, Teacher-Advisor

Earthbound experiments have already indicated that silkworms, in spinning their cocoons, employ gravity as an environmental clue. This experiment will observe the effects a zero-gravity environment will have on silkworms spinning cocoons in the Space Shuttle.

"The Effects of Weightlessness in Space Flight on the Healing of Bones."

Andrew I. Fras

Binghamton, NY
Binghamton Central High School
Howard Fisher, Teacher-Advisor
*STS-14
Orthopedic Hospital
University of Southern California, Los Angeles, CA

General Dynamics/Convair Division, San Diego, CA

This experiment was designed to study the effects of space on changes in bone growth and repair.

"Atmospheric Pollutant Location and Concentration Determination Using Spectroscopy."

Jeff B. Fuchs

Livonia, MT

Adlai E. Stevenson High School

Donald O. Bundy, Teacher-Advisor

This experiment is designed to determine the locations and relative concentrations of certain atmospheric pollutants above selected sections of the Earth's surface through the use of spectroscopy—the study of the dispersed light from an object.

"Observation of Various Gravity Induced Phenomena of Oat Coleoptiles in a Zero-Gravity Environment."

Edward W. Gulley

Winston-Salem, NC

R. J. Reynolds High School

Barbara Stelter, Teacher-Advisor

Corn and oat coleoptiles will be positioned in space, with half oriented perpendicular to the others. They will be preserved in space with a fixative and examined postflight for changes in callose formation and the distribution pattern of calcium ions and amyloplasts.

"Effects of Deuterium Oxide on Plant Growth in a Zero-Gravity Environment."

Douglas D. Hensley

Parkville, MO

Park Hill High School

Richard Kavanaugh, Teacher-Advisor

The objective of this experiment is to explain the mechanisms involved in the inhibitory effect of heavy water or deuterium oxide ($2H_2O$) on plant growth. It will determine if growth inhibition is due to impaired RNA synthesis or retardation of osmosis due to the greater mass of the $2H_2O$.

"Monitoring the Effects of Simulated Gravity on Plants."

William D. Loftis, Jr.

Scott Depot, W VA

Winfield High School

Allieta Machmer, Teacher-Advisor

The object of this experiment is to see whether centrifugal force, as a gravity substitute, affects the generation and growth of bean and mustard plants at the 1 g, 1/2g simulated gravity levels, and at the zero-gravity level.

"Quantitative Confirmation of Einstein's Theories of General and Special Relativity."

Timothy D. Maclay

Springfield, PA

Springfield High School

Joseph Zumpano, Teacher-Advisor

The purpose of this experiment is to confirm quantitatively the simultaneous effects due to both Einstein's General and Special Relativity theories by comparing atomic clocks—one to be flown on the Shuttle and the other to remain on Earth.

"The Purification and Growth of Single Crystal Gallium by the Float Zone Technique in a Zero-Gravity Environment."

Shawn P. Murphy

Newbury, OH

Newbury High School

Rexford Roberts, Teacher-Advisor

*STS-16

Rockwell, Downey, CA

For this experiment, a single crystal of gallium doped with thallium will be grown in space and compared to a crystal grown in an identical manner on Earth. In the absence of gravity, a more uniform distribution of the thallium and a more perfect gallium crystal should result.

"Zero Gravity Growth of Ice Crystals from Supercooled Water with Relation to Temperature."

Tracy L. Peters

Walnut Creek, CA

Ygnacio Valley High School

James R. Cobb, Teacher-Advisor

*STS-16

Boeing Company, Seattle, WA

This experiment will observe the formation of ice crystals at various supercooled temperatures below zero centigrade in a gravity-free environment. Absence of gravity will allow for a better understanding of the relationship between temperature and crystal geometry by eliminating faults.

"Investigation for Arc and Ion Behavior in Microgravity."

Gregory S. Peterson

Salt Lake City, UT

Box Elder High School

Darrell Turner, Teacher-Advisor

*STS-17

Morton/Thiokol, Brigham City, UT

This experiment is designed to study arc behavior in microgravity. The diffusion and turbulent mixing of gaseous ions and the determination of minimum energy paths for successive arc discharges will be determined by use of the arc source called a Jacob's ladder.

"A Comparison of Honeycomb Structures Built by Apis Millefera."

Dan M. Poskevich

Waverly, TN

Waverly Central High School

Andrew S. Hendrix, Teacher-Advisor

*STS-11

Honeywell, Clearwater, FL

A premature colony of bees will be flown aboard the Shuttle to examine the effect of weightlessness on honeycomb construction.

"The Effects of Heat, Light, and Zero Gravity on the Tunneling Habits of Earthworms."

Scott M. Tyner

LaGrangeville, NY

Arlington High School

Jan L. Stoutenburgh, Teacher-Advisor

This experiment will compare the tunneling habits of 10 earthworms flown aboard the Shuttle with the behavior of 10 worms in a control experiment on Earth.

"Measurement of Auxin Levels and Starch Grains in Plant Roots."

Chia-Lien Wang

Waco, Tx

Richfield High School

John Wilson, Teacher-Advisor

Bean plants will be grown and then frozen in space. The plant roots will be analyzed postflight for auxin location and concentration and correlation with statholith location in the cells.

"The Effects of Microgravity on Red Blood Cell Mass in Horizontally Oriented Species Versus Vertically Oriented Species."

Timothy R. Young

Madison, WI

West Senior High School

Gary Craper, Teacher-Advisor

This experiment will investigate the process that stimulates a decrease in red blood cell mass of goldfish in a weightless environment.

*Pending flight

SSIP 1982-83

"Immunological Reactions in Zero Gravity."

Elizabeth A. Campbell

Prairie Village, KS

Shawnee Mission East High School

Rick Gould, Teacher-Advisor

The basic objective of this project is to evaluate the degree to which immunological reactions are influenced by gravity. Blood typing reactions of the ABO and Rhesus systems will be used because of their common use in blood banking and the direct applications to space medicine. The designed apparatus will facilitate the attachment of red blood cells to specific antibodies in a closed system. The intensity of this reaction will be tested through the use of several standard laboratory analyses. Comparisons between the data

collected in zero gravity and gravity-influenced environments should demonstrate whether gravity plays a role in immunological reactions.

"Zero-g Capillary Rise of Fluid Through Granular Porous Media."

Constantine N. Costes

Huntsville, AL
Randolph School
Edgar D. Mason, Teacher-Advisor

The behavior of a wetting liquid through densely packed assemblies of equal-sized glass spheres, with smooth and chemically clean surfaces, will be studied through flow measurements/observations, photographic documentation, and examination of specimens returned to Earth. Because of the micro-g environment of the Space-lab, this experiment should significantly advance our understanding of capillary fluid flow behavior through coarse granular media, which is of primary importance to many disciplines on Earth but difficult to isolate from gravitational effects.

"The Effect of Weightlessness on the Aging of Brain Cells."

Andrew I. Fras

Binghamton, NY
Binghamton High School
Howard B. Fisher, Teacher-Advisor

Spaceflight causes tissue deterioration closely resembling aging. The causal role of weightlessness has usually been viewed as indirect: absence of anti-gravity activity produces disuse atrophy whose symptoms are similar to aging. However, there is reason to believe that weightlessness *per se* plays a specific role. A controlled experiment using matched houseflies is expected to show accelerated aging in their brain cells, as a result of an increased accumulation of age pigment in, and deterioration of, the neurons. If the experiment should confirm this hypothesis, it will signal the need for artificial gravity to counteract the danger of premature aging and resulting loss of brain function during prolonged stay in space.

"A Study of Paper Fiber Formation in Micro-Gravity."

Daniel J. Hebert

Appleton, WI
Appleton High School-West
David W. McKay, Teacher-Advisor

To further increase basic papermaking knowledge, this project proposes a drainage study of paper fiber formation in micro-gravity and a comparison to formation under Earth conditions. Each experiment has a nine-tube apparatus with different fiber, polymer, and water mixes. In space, the water will be drained through a screen as the various polymers control the floccing, leaving a fiber mat. These mats will be analyzed for formation characteristics and compared to those of the control.

"Effects of Conditions in Outer Space on Hemoglobin."

Daniel B. Saal

West Orange, NJ
Yeshiva University High School for Boys
Albert S. Tarendash, Teacher-Advisor

By performing spectrophotometric studies of hemoglobin's O₂ binding in space and on Earth, a number of questions can be answered. These questions include the cause for "space anemia," the function of hemoglobin and related allosteric proteins in space, and the effects of conditions in space on molecular function. It is proposed that micro-gravity affects hemoglobin's dimer-dimer motion. This would alter the hemoglobin's O₂ affinity.

"Argon Injection in Gallium as an Alternative to Honeycombing."

Rachel M. Safman

Gaithersburg, MD
Montgomery Village Junior High School
Edward I. Johnson, Teacher-Advisor

This experiment will investigate the feasibility of producing a high stiffness: density ratio, low-weight casting with an internal framework.

Argon gas would be injected into molten metal. These gas bubbles, "placed" at specific intervals, would expand, forcing the metal to the shape of the mold and producing hollows in the metal.

Some problem areas anticipated include surface tension and the natural attraction between bodies. Comparative testing would be done on Earth, including cross-sectioning.

"An In-Vitro Study of Bone Decalcification in Weightlessness, and the Effects of Calcitonin, Dichloromethane Diphosphonic Acid, Fluoride, and Axial Pressure on the Rate of Decalcification."

Alexander H. Swirnoff

Bayside, NY
The Bronx High School of Science
Madeline Schmuckler, Teacher-Advisor

Purposes of the experiment are to:

- (a) gain quantitative data on calcium loss from chicken tibiae in culture in weightlessness;
- (b) determine if calcitonin and other chemicals can reduce decalcification;
- (c) determine if continuous pressure on bone affects decalcification.

A growth chamber has been designed to house bones and separate bones from media, retaining each for later analysis.

Calcium loss will be measured using a radioactive tracer. Statistical analyses of data will be performed.

"Effects of Zero- and Micro-gravity on the Grey Crescent in Polyspermic, Monospermic, and Parthenogenetically Activated Amphibian Embryos."

Michael Thaddeus

New York, NY
Hunter College High School
Lester A. Rubenstein, Teacher-Advisor

The grey crescent, a streak which appears on the amphibian egg shortly after fertilization, is mysterious in both its origin and its function, although it clearly plays a major role in the establishment of bilateral symmetry. Experiments with parthenogenesis and tilting out of the usual gravitational orientation have shown that gravity is one factor determining its location. Observing the grey crescent in zero gravity and its location relative to other dorsal structures in both fertilized and parthenogenetically stimulated eggs would yield valuable information about its origin and function. The degree of sensitivity of the dorsalization process to gravity can also be determined by using centrifugation to subject the embryos to levels of "gravity" between zero and full Earth value.

"Chicken Embryo Development in Space."

John C. Vellinger

Lafayette, IN
Jefferson High School
Stanley W. Poelstra, Teacher-Advisor

This proposed experiment will work with chicken embryos. Twelve white Leghorn chicken eggs will be placed in an incubator box and sent into space while an identical group will remain on Earth. The susceptibility of any cell is greatest during its developmental stages; therefore, the developing chicken embryo will be studied. The development of the chicken embryo will have applications toward the possible development of man in space.

Chickens could be an excellent food source in space. If this is to happen, the normal development of the embryo must take place in a weightless environment. Eight eggs will have their internal organs, cartilage, bone and digit structures, muscle systems, nerve system, and facial structures studied. The remaining four eggs will be surrounded with a lead shield to study the effects of space radiation on normal chicken development.

"Thin Layer Metallic Crystal Formations with Respect to Direct Current and Ultrasonics."

Lori H. Woodward

Brush, CO
Brush High School
Linda J. Preston, Teacher-Advisor

How will metallic crystal formation be affected by a weightless environment? Viewing cells, filled with various saturated chemical solutions, will be connected to a 6V power source. Ultrasonics will be added as a variable. Photographic analysis through a microscope will be done at 5-second intervals for one minute. Final comparative analysis will be made with tests completed on Earth.

SPACE SHUTTLE ACTIVITIES



This is the official insignia chosen by NASA for the Space Shuttle. Specific Shuttle activity may be identified in a separate rectangular block added to the bottom of the insignia.

SOME SUGGESTIONS FOR USING SPACE SHUTTLE ACTIVITIES

1. "25 YEARS WITH NASA" - Run off copies and have students find the answers; or, have individual students take one of the descriptions and find the year in which it happened, get a picture or make a drawing to illustrate it. Make a large poster with all of the illustrations and descriptions the students turn in. Or, you could arrange the illustrations and descriptions in chronological order around the room.
2. "The Space Shuttle" - Use as a pre-"test" to a study of the Shuttle.
3. "Shuttle to Space" - Get a copy of the film, "Shuttle to Space," from your regional office of NASA (See Appendix) or, if you are close to Rochester, Mi, from the Aviation and Space Center at Oakland University.
4. "The Space Shuttle Awareness Test" - Use as a lead in to a discussion of the Shuttle.
5. Answers to the above Activity Sheets.
6. "Space Transportation System" - Have the students see how many they can do before a study of the STS and have them redo after they have done some searching for information.
7. "Space Shuttle Orbiter" - This is really super if you have an area where the Orbiter outline can be marked off with string or powdered chalk.
8. "The Space Shuttle Game" -
 - a. Make copies of all 8 pages.
 - b. Glue the first two pages (the gameboard) to a sheet of cardboard 11 x 17. Color the gameboard and laminate it.
 - c. Take the first set of questions and glue to a sheet of tag-board 8½ x 11 and glue the corresponding set of answers on the back. Cut apart and laminate.
 - d. Repeat (c) for next two sets of questions and answers.

As the students play the game and study the Shuttle, have them make up new questions for the game.

9. Shuttle Pictures and Information.

25 YEARS WITH NASA

MATCH THE EVENTS LISTED BELOW WITH THE YEAR IN WHICH THE EVENT HAPPENED.
CHOOSE FROM YEARS FOLLOWING: (A few will be used more than once.)

1958	1963	1968	1975	1983
1960	1964	1969	1976	
1961	1965	1972	1977	
1962	1966	1973	1981	

- _____ 1. The Viking program landed two spacecraft on Mars, 40 million miles distant and put two others in orbit around the Red Planet. The Orbiters mapped the Martian surface and relayed communications from the Landers which took photos of the surface, sampled the soil and the atmosphere, and conducted a search for extraterrestrial life signs. They didn't find any.
- _____ 2. After six prior failures, three Ranger spacecraft acquired closeup photos of the moon's surface as a preliminary step toward manned landings. Whew!
- _____ 3. Gemini 6 takes a picture of Gemini 7 in space, the first photograph of an orbiting spacecraft made during the first rendezvous between two spacecraft. During the same flight, Edward White became the first U.S. astronaut to take a walk in space. He had such a good time he told James McDevitt, "I'm not coming in...This is fun!"
- _____ 4. The newly formed NASA launched its first spacecraft, Pioneer 1, which failed to reach the moon but climbed to a record altitude of more than 70,000 miles.
- _____ 5. Landsat 1, the first of four Earth resources survey satellites is launched. Equipped with cameras and sensors, the satellites offer a means of monitoring changing conditions on Earth's surface for practical benefit in such applications as agricultural crop forecasting, mineral and petroleum exploration, forest management, mapping, land use management, water quality evaluation and disaster assessment. Watch out. Landsat's watching you!!
- _____ 6. Another first -- Mariner 10 provides the first close-up views of Mercury, smallest of the solar system's nine planets and the most difficult to observe from ground-based telescopes because it is close to the Sun. Oh yes, and while it was out it took pictures of Venus, too. A very efficient little spacecraft....

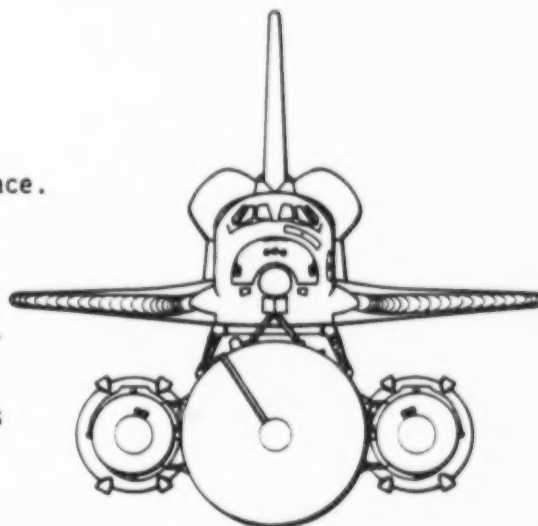
- _____ 7. Launch of IRAS, the Infrared Astronomical Satellite, inaugurates NASA's silver anniversary. IRAS sensitive instruments have discovered stars being born, stars dying, and galaxies so small and so distant they have been viewed only dimly before, some not at all.
- _____ 8. Some Americans by the name of Stafford, Slayton and Brand met up with two Russian fellows in Space named Leonov and Kubasov. The mission was called Apollo-Soyuz and for awhile Russians and Americans smiled at each other like buddies.
- _____ 9. Skylab was launched and in this and the next year, three three-man crews manned the station for stays of 28, 59 and 84 days. Skylab provided important medical data on the effects of long duration weightlessness, a great amount of invaluable astronomical and Earth resources data, and a technology base for planning a permanent space station. And, even after 84 days in that little thing, they were still speaking to each other.
- _____ 10. One of the most historic moments in the history of the United States: the planting of the American flag on the Moon, witnessed by two-thirds of the world's people. Twelve men have walked the Moon's surface and Neil Armstrong was the first. What does a person do for an encore after something like that?!
- _____ 11. Pioneer 10 departed Earth in our first attempt to send automated vehicles beyond the solar system. A year later Pioneer 11 followed and the two interplanetary explorers sent back data and photos of Jupiter and Saturn, then continued onward toward... heaven knows where.
- _____ 12. Syncom 2 and Syncom 3 were put into synchronous orbit so that Earth could have 24-hour service. The two satellites, orbiting at 22,300 miles above the Equator, provided the foundation for the commercial communications satellite networks that followed. It is distinctly possible that without this early technology, MTV would never have gotten off the ground!
- _____ 13. Surveyor became the first U.S. spacecraft to land on another celestial body. Surveyor photographed the moon from surface level and conducted experiments to demonstrate that the surface was not made of green cheese and would support a manned spacecraft.
- _____ 14. NASA began flight tests of the X-15 rocket-powered research airplane. The X-15 provided scientific data from altitudes of more than 40 miles, where people had never been before, and topped 4,500 miles per hour, the fastest a winged vehicle had ever flown. Those speeds could take you from Detroit to Rome, Moscow, Hawaii or Brazilia in just about one hour or you could fly from Detroit to Lansing in just over one minute. Fast!

- _____ 15. OAO-2 was the first of two successful Orbiting Astronomical Observatories; its companion, OAO-3 or Copernicus, was launched four years later. These big observatory class satellites, weighing well over two tons, brought a new dimension to space astronomy. With their arrays of sensitive instruments and extremely precise star-pointing systems, they provided volumes of new data about the stars and galaxies.
- _____ 16. Voyager 2 spacecraft left in August; Voyager 1 left in September. (Don't you wonder why 2 went 1st and 1 went 2nd? There was a very reasonable explanation...) The two spacecraft returned tens of thousands of photos and countless volumes of scientific data on Jupiter and Saturn during their grand tour of the solar system. Voyager 2 is en route to encounters - in the latter 1980's - with Uranus and Neptune, neither ever visited by spacecraft. At that point, only Pluto, that little bitty planet about 4,000,000,000 miles from Earth will be unvisited by American spacecraft.
- _____ 17. Alan Shepard's suborbital flight of 15½ minutes in Freedom 7 inaugurated U.S. manned space flight only 23 days after the Soviets orbited the first cosmonaut, Yuri Gagarin. A year later, NASA put a man in orbit for the first time. It's been quite a race.
- _____ 18. Mariner 2 scored a major U.S. triumph in the space competition with the Soviet Union: it was the first successful planetary probe. It traveled 48 million miles to Venus, passed within 22,000 miles of the planet and measured Venus' atmosphere, surface temperature and other phenomena. Among other things, the spacecraft told us we probably wouldn't want to buy a piece of property there: if the 220 mph winds don't get you, the atmosphere, made up of suspended particles of sulphuric acid, undoubtedly will.
- _____ 19. Astronaut John Glenn boarded his Mercury spacecraft, Friendship 7, and became the first U.S. astronaut to orbit the Earth. He made three orbits in five hours. Doesn't seem like much now but it was SPECTACULAR that year.
- _____ 20. A major milestone--the Space Shuttle Columbia lifted off the pad at Kennedy Space Center on its first voyage to space. The Shuttle is the first true aerospace vehicle: launched like a rocket, it orbited like a spacecraft and landed like an airplane (well, a glider may be a more precise term since it has no fuel to fly it with). The Shuttle, with its reusable components - only the external tank is expendable - ushered in a whole new era of operational regularity and expanded opportunities for the practical benefits space promises.

The Space Shuttle

EACH OF THE FOLLOWING SENTENCES DESCRIBES SOME PART OF THE SPACE TRANSPORTATION SYSTEM (SPACE SHUTTLE). SELECT THE LETTER OF THE PROPER WORD THE SENTENCE DESCRIBES FROM THE LIST ON THE RIGHT. PLACE THIS LETTER IN THE BLANK IN FRONT OF THE SENTENCE ON THE LEFT.

- | | |
|---|------------------------------|
| ____ 1. The area of the Shuttle where the cargo is stored. | A. Spacelab |
| ____ 2. The part of the STS which lands on the Earth as a glider. | B. Solid Rocket Boosters |
| ____ 3. A payload of the Shuttle which will be sent on to Jupiter. | C. External Tank |
| ____ 4. A part of the Shuttle which could supply extra energy for operating the Orbiter. | D. Cabin |
| ____ 5. The Shuttle part which will allow scientists to work in weightless conditions. | E. Galileo on Centaur |
| ____ 6. Provided on the Shuttle so the astronauts would be able to work outside the Orbiter. | F. Satellites |
| ____ 7. The Shuttle payload which will give astronomers on Earth a ten times better view of the Universe. | G. Remote Manipulator System |
| ____ 8. Part of the Shuttle which supplies 5 million pounds of thrust for the first two minutes of the mission. | H. Spacesuit |
| ____ 9. The 50' mechanical arm used by astronauts to deploy payloads into space. | I. Power Extension Package |
| ____ 10. Objects placed into space by using the Shuttle's remote arm which could help us forecast weather, communicate and record land resources. | J. Orbiter |
| ____ 11. The part of the Shuttle system which provides the liquid fuel for Orbiter's engines. | K. Space Telescope |
| ____ 12. The area of the Orbiter where the crew lives and works. | L. Payload Bay |



Courtesy of NASA

"SHUTTLE TO SPACE"
ACTIVITY SHEET

DIRECTIONS: The missing words in the following statements can be found in the film, "Shuttle To Space". Fill in the blanks with the correct words.

1. Like the oceans, forests and the soil, space is one of our natural _____.
2. The Space Shuttle's main job is to transport _____ back and forth between earth and space.
3. The first practical rockets were fireworks built about one thousand years ago by the _____.
4. Dr. Robert Goddard adapted the _____ to control the flight of the _____.
5. In the 1930's the _____ Rocket Society began developing what were then considered to be large rockets.
6. The NASA facility in Huntsville, Alabama where Wernher von Braun and other German scientists have done research into space travel is called the _____.
7. On October 4, 1957 the Soviet Union surprised the world by launching into space a small _____ named _____.
8. The first American satellite was named _____.
9. Because our rockets could not lift heavy weights, the tiny _____ was developed to replace the bulky _____.
10. The first man to step onto the surface of the moon was _____.
11. The part of a space vehicle which boosts the entire vehicle to a desired position in space is called a _____.
12. The portion of the space vehicle which will accomplish a particular mission in space is called the _____.
13. Before the Space Shuttle, payloads returning to earth used a _____ system to land in the ocean.

14. The new reusable space vehicle which will carry people and cargo into orbit at a lower cost is called the _____.
15. Two Solid Rocket Boosters help overcome earth's _____ during launch.
16. After the Solid Rocket Boosters separate from the Shuttle, the Orbiter continues toward space using fuel and _____ from the External _____.
17. Small engines provide the minor _____ needed to place the Orbiter into a working _____.
18. Special tiles protect the Orbiter from tremendous _____ caused by air friction as it re-enters the atmosphere.
19. Satellite photographs taken with both a normal and an _____ can provide us with a wealth of information about earth and sea resources.
20. Because the _____ blurs the earth view of the universe, the Space _____ will be orbited above it.
21. High school students have an opportunity to fly their own experiments on the Shuttle under the _____ program.

Every word used to fill in the blanks can be found in this word search puzzle. The words in the puzzle may be read vertically, horizontally, diagonally, and backward. Draw a line around each word.

```

C A T M O S P H E R E M O R
C R H O G R A C L T X R S E
H E G C R O A L O G B A C R
I T I A V P A L E I Q R R O
N N L M S H U T T L E S O L
E E F E S P A C E P P R C P
S C W R N W E Y O B O O K X
E J A A A A W C X R C T E E
C M T Y L R S C I H S S T F
A E U H S O E A D A E I U S
Y M B V R R Q D I P L S H N
T G E Y T U F D Z L E N C D
I V C B O O S T E R T A A A
V A E C K N A T R A B R R O
A C R S T T A E H K L T A L
R U M E A S P U T N I K P Y
G U A S E C R U O S E R A A
R M N A R M S T R O N G P P

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Courtesy of NASA

SAT

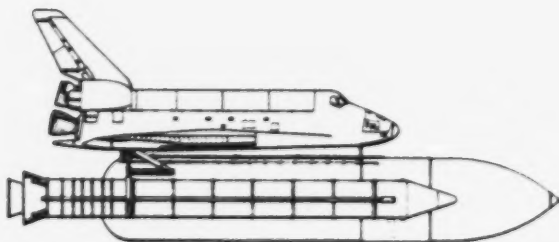
THE SHUTTLE AWARENESS TEST....

THE FOLLOWING QUIZ REQUIRES ONLY ONE ANSWER PER QUESTION. THE STATEMENTS ARE EITHER TRUE OR FALSE. THEY WERE DESIGNED TO ILLUSTRATE CERTAIN POINTS ABOUT THE SPACE TRANSPORT SYSTEM KNOWN AS THE SHUTTLE.

1. The shuttle will never fly to the moon.
2. The muffler for the shuttle is made of water.
3. You can breathe the fuel used by the three main engines of the shuttle.
4. The robot arm of the shuttle can lift up to 32 tons in space but can not lift itself on the ground.
5. The shuttle can carry up to seven people into space.
6. The cargo bay of the shuttle is long enough to park a schoolbus and a family car.
7. The payload specialists who will go into space are not astronauts.
8. The toilet on the shuttle uses no water.
9. In orbit, the shuttle can go from one end of this country to the other in about twelve minutes.
10. The space shuttle could land at any major airport.

Bonus question...True or False: the drinking water for the crew is made while in space.

Courtesy of NASA,
Spacemobile Program



—ANSWERS—

"25 YEARS WITH NASA"

1. 1976
2. 1964
3. 1965
4. 1958
5. 1972
6. 1973
7. 1983
8. 1975
9. 1973
10. 1969
11. 1972
12. 1963
13. 1966
14. 1960
15. 1968
16. 1977
17. 1961
18. 1962
19. 1962
20. 1981

"THE SPACE SHUTTLE"

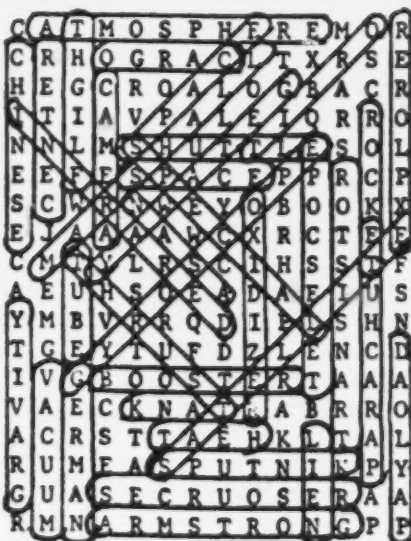
1. L
2. J
3. E
4. I
5. A
6. H
7. K
8. B
9. G
10. F
11. C
12. D

"SHUTTLE TO SPACE" Activity Sheet

1. resources
2. cargo
3. Chinese
4. gyroscope, rocket
5. German
6. Marshall Space Flight Center
7. satellite, Sputnik
8. Explorer
9. transistor, vacuum tube
10. Neil Armstrong
11. Booster
12. Payload
13. parachute
14. Space Shuttle
15. gravity
16. oxidizer, Tank
17. thrust, orbit
18. heat
19. infrared camera
20. atmosphere, Telescope
21. NASA Getaway Special

"SHUTTLE TO SPACE"

Word Search

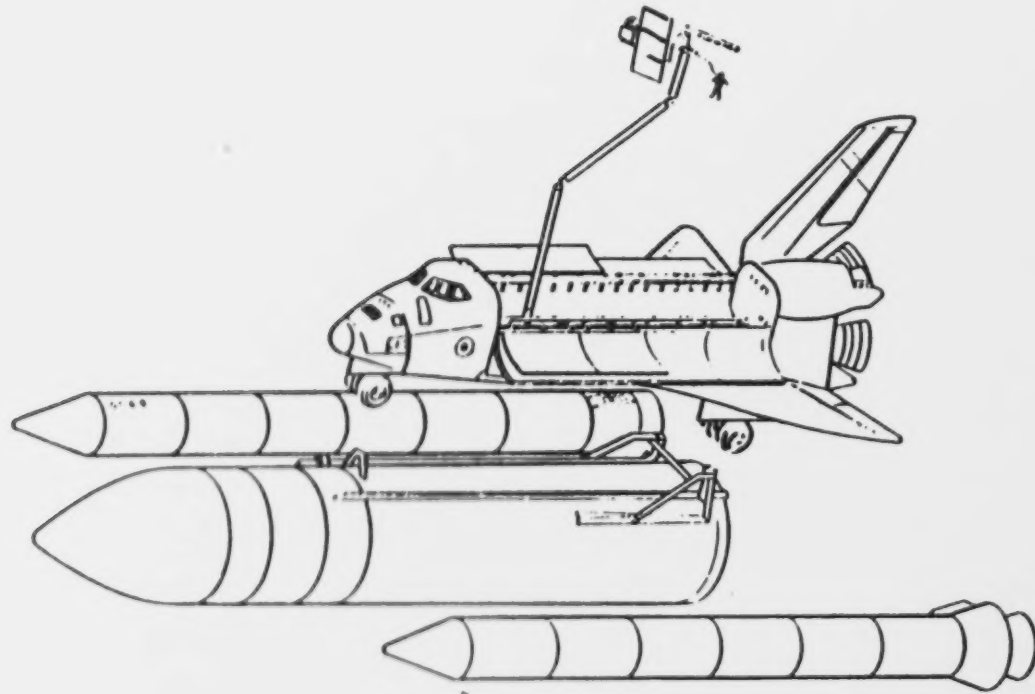


"SHUTTLE AWARENESS TEST"

Answers 1 - 10 are all true.
So is the bonus question.

Space Transportation System

DRAW A LINE FROM THE NAME OF THE SHUTTLE
PART TO ITS PROPER PLACE ON THE DRAWING.



ORBITER

ASTRONAUT

SIDE HATCH

CREW CABIN

PAYLOAD BAY

MANIPULATING ARM

STAR TRACKER DOOR

SATELLITE

ELEVONS

SOLID BOOSTER

MAIN LANDING GEAR

NOSE LANDING GEAR

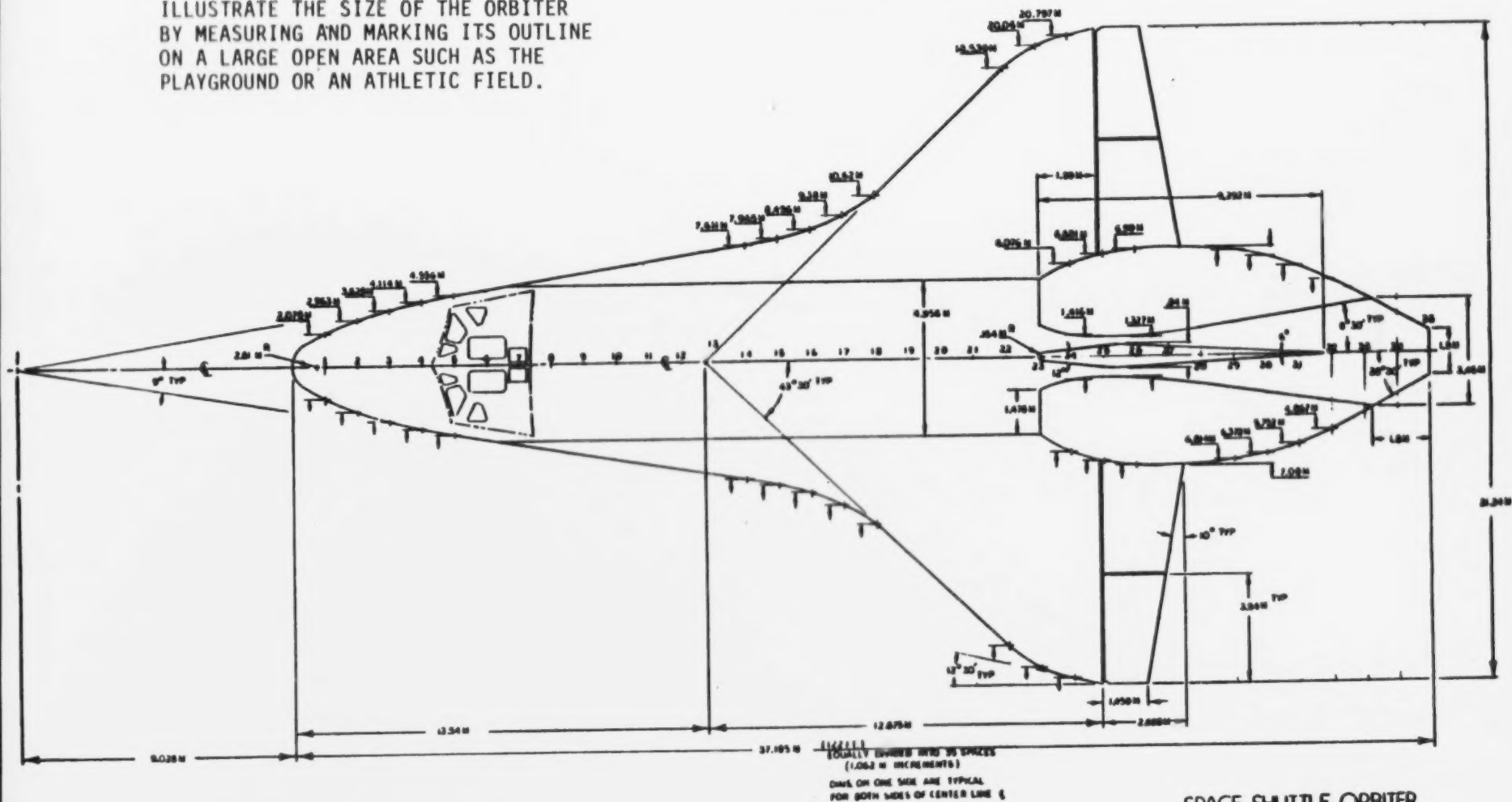
RUDDER / SPEED BRAKE

EXTERNAL FUEL TANK

MAIN PROPULSION ENGINE

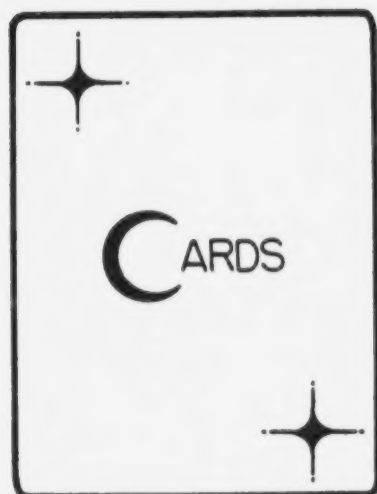
FORWARD REACTION CONTROL ENGINE

ILLUSTRATE THE SIZE OF THE ORBITER BY MEASURING AND MARKING ITS OUTLINE ON A LARGE OPEN AREA SUCH AS THE PLAYGROUND OR AN ATHLETIC FIELD.

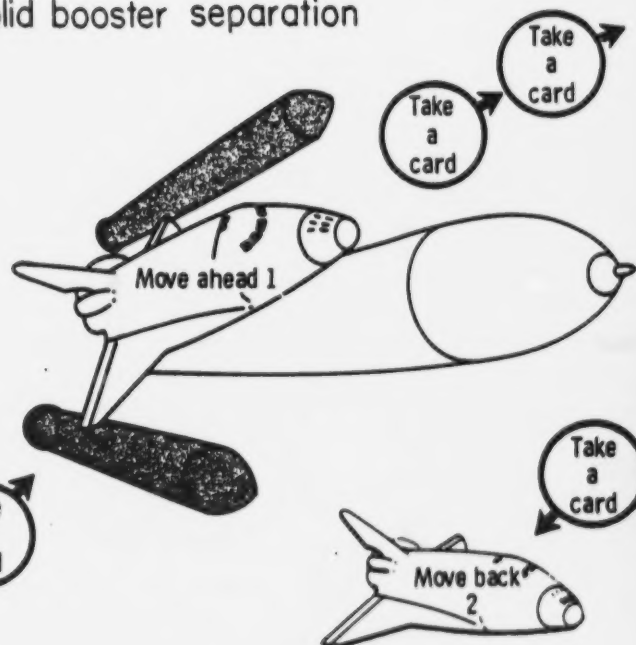


SPACE SHUTTLE ORBITER

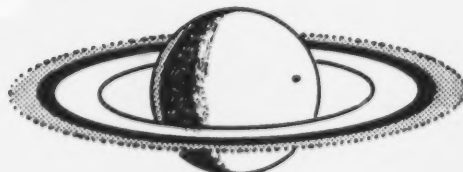
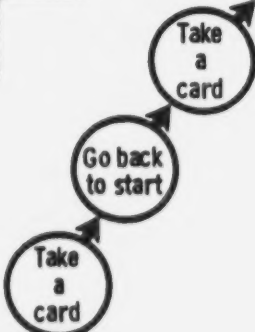
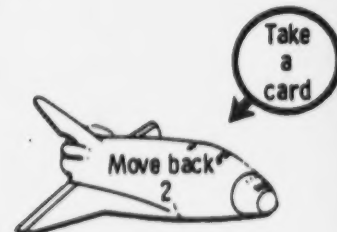
PREPARED FROM
ROCKWELL INTERNATIONAL
SPACE DIVISION
MODEL INFORMATION
BY
DAVE MORRIS 2-10-79

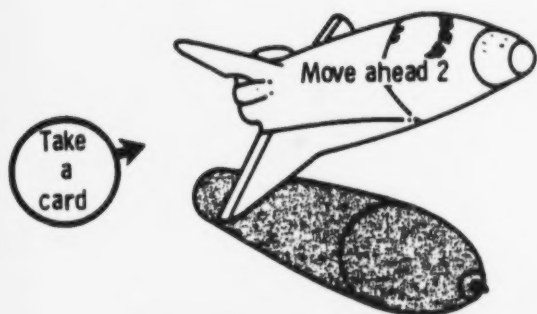


Solid booster separation

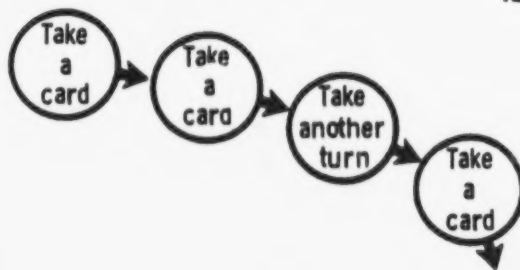


Fire retro-rockets to slow down for reentry

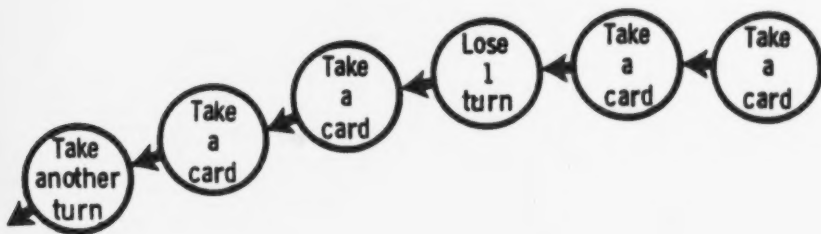




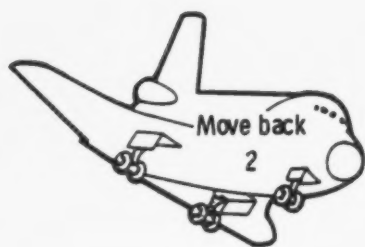
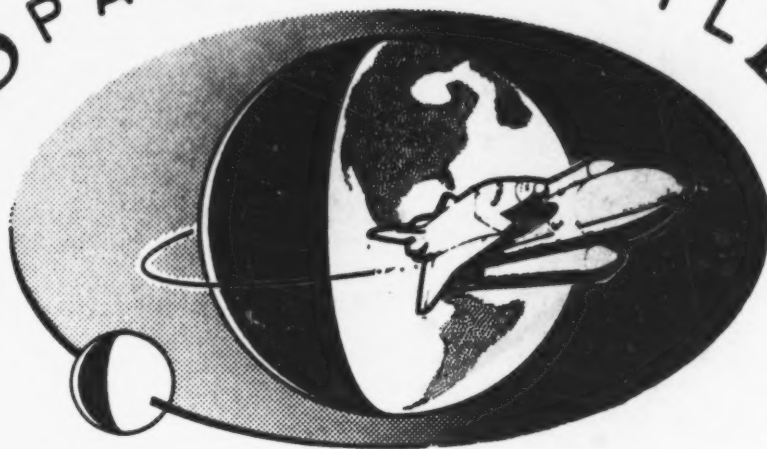
External tank separation



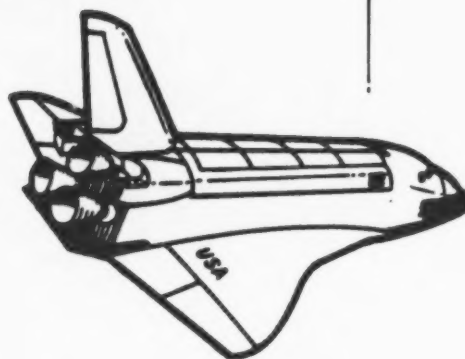
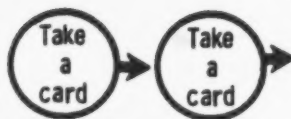
Fire engines to adjust orbit



SPACE ★ SHUTTLE



Lower landing gear



LANDING

A termination of a flight or mission is called.....	A chamber which allows passage of the crew from crew quarters to the laboratory (Spacelab) in the cargo bay of the Shuttle is called...	A structure that is supported in flight by the dynamic action of the air against its surface is....
To come close to the landing site is to _____ it.	A person designated to be a pilot, commander or mission specialist by NASA to perform scientific and/or engineering tasks in space is known as.....	The gaseous mass which surrounds a celestial body; a whole mass of air surrounding the Earth is.....
What is worn on the back and used as a life support system for extra-vehicular activity?	What is the short span of time during the deorbit when the Orbiter is out of touch with communication and tracking systems called?	The process of removing the water from an object is called.....
To come out of orbit is to.....	To go outside the spacecraft is to	What is the cell that continuously changes the chemical energy of a fuel and oxidant to electrical energy or a power source for the Shuttle such as a battery in a radio?
What is the force exerted on an object/mass that holds it to the surface of the Earth or pulls objects toward the surface of the Earth?	The building where the Shuttle is housed is called a.....	When something can be blown-up (similar to a balloon) it is said to be....
The area on the Shuttle where scientists experiment and collect data is called the.....	The acronym for "main engine cut-off."	The space jargon for "Everything is fine" or "It's A-OK."
A path described by one body in its revolution about another.	The reusable vehicle in the Space Transportation System that is used for missions in Space is called the....	An element that is found free as a colorless, tasteless, odorless gas in the atmosphere is....

An Aircraft

Airlock

Abort

Atmosphere

Astronaut

Approach

Dehydration

Black-out

Backpack

Fuel Cell

Extra-vehicular
activity

Deorbit

Inflatable

Hangar

Gravity

Nominal

MECO

Spacelab or
Cabin

Oxygen

Orbiter

Orbit

A paid or useful load that a vehicle can carry is called a.....	A force per unit area is called....	The act of putting water back into something that has had the water extracted is called....
The mechanical arm used on the Shuttle to aid in the mission is the....	A vehicle that is propelled by a rocket engine that is an action-reaction device is a	A clearing that has been made and constructed for the landing of an aircraft is called the
A smaller body circling a larger body is a....	Clothes worn by astronauts for EVA.	A mechanical piece of scientific equipment, a manned or unmanned device designed to orbit the Earth or to travel beyond the Earth's atmosphere is a
To use a technical method to achieve a practical purpose is to use	What is the tube or rope restraint used to fasten an astronaut to the Orbiter but allows him/her a length which does not hinder movement and ability to do work?	What is the absence of air and pressure?
Lacking apparent gravitational pull is called....	What are the four main parts of the Shuttle?	What provides the major portion of the thrust at the time of the Shuttle's liftoff?
The _____ contains the propellants used for liftoff and ascent by the Shuttle Orbiter's three main engines.	How many main engines are there on the Shuttle?	What are the two main propellants contained under pressure in the External Tank?
The cargo bay can carry up to how many satellites for launching at one time?	The Orbiter is propelled by how many rocket engines used in various combinations for liftoff, attitude control and reentry?	The forward section of of Orbiter contains the _____ and the _____.

Rehydration

Pressure

Payload

Runway

Rocket

Remote Manipulator
System
(RMS)

Spacecraft

Spacesuit

Satellite

Vacuum

Tether

Technology

Solid Rocket Boosters

Orbiter
External Tank
2 Solid Rocket
Boosters

Micro-Gravity or
Weightlessness or
Reduced Gravity

Liquid oxygen
Liquid hydrogen

Three

External Tank

Flight deck
Crew quarters

49

Four

Name two Orbiters.	The Shuttle Orbiter rides piggy back on what plane?	What does ESA stand for?
What does NASA stand for?	What is the only major part of the Shuttle that is discarded during ascent to orbit?	How many meters long is the Orbiter?
The Shuttle is constructed mostly of _____ alloy.	The Shuttle orbits between _____ mph and _____ mph.	How many g's do those aboard the Shuttle pull on liftoff?
How many computers are there on the Shuttle?	The personal rocket kit used by astronauts to fly outside the cargo bay is called the.....	The Shuttle's main engines and the Solid rocket boosters provide approximately how many newtons of thrust at liftoff?
On average, how long does it take the Shuttle to orbit the Earth once?	True or False: There will be three orbiters fully operational in the future.	True or False: Water spilled inside the orbiter by an astronaut will fall quickly to the floor.
True or False: The spacebeds on the Shuttle are both vertical and horizontal.	True or False: There is a seat belt on the toilet aboard the Shuttle.	True or False: The minimum crew for a Shuttle mission is five.
True or False: The first orbiter to successfully be launched by NASA was the Atlantis.	True or False: The Shuttle is launched from Houston, TX.	True or False: Orbiters have been named for Navy ships.

European Space Agency

A 747

Challenger
Columbia
Discovery

Atlantis

37

External Tank

National Aeronautics and
Space Administration

3

17,000 to 18,000 mph

Aluminum

30,800,000

Manned Maneuvering Unit

five

(4 simultaneous and
1 backup)

False

False

90 minutes

False

True

True

True

False

False



Space Transportation System



Shuttle System/Orbiter Cutaway



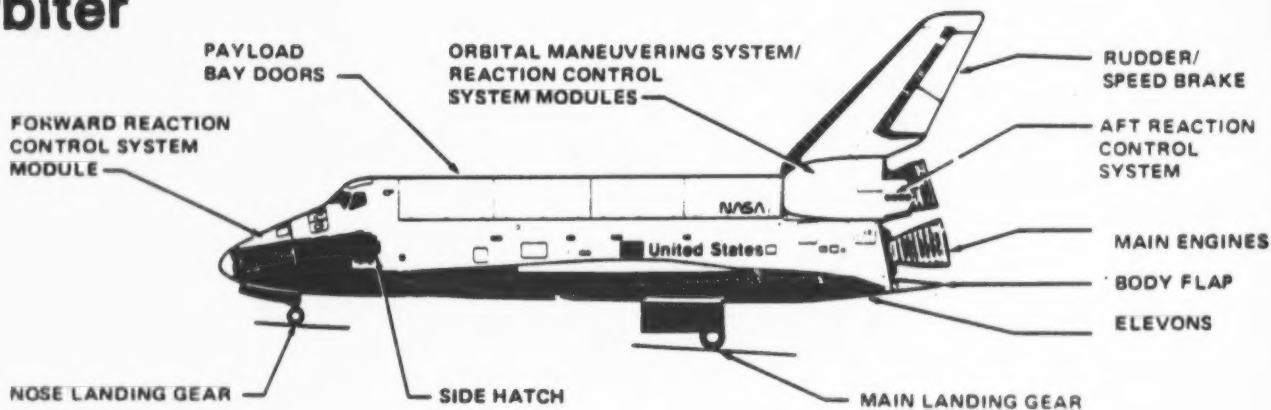
Space Transportation System



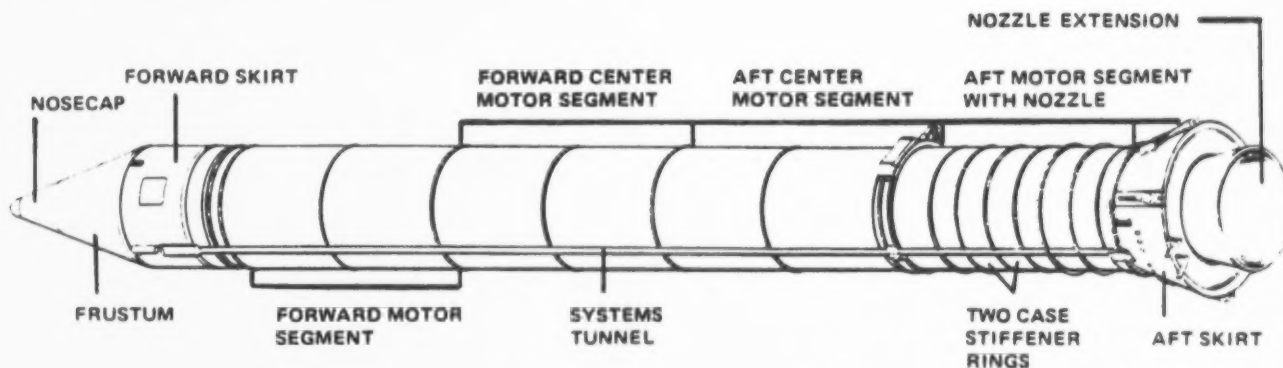
Spacelab

Space Shuttle

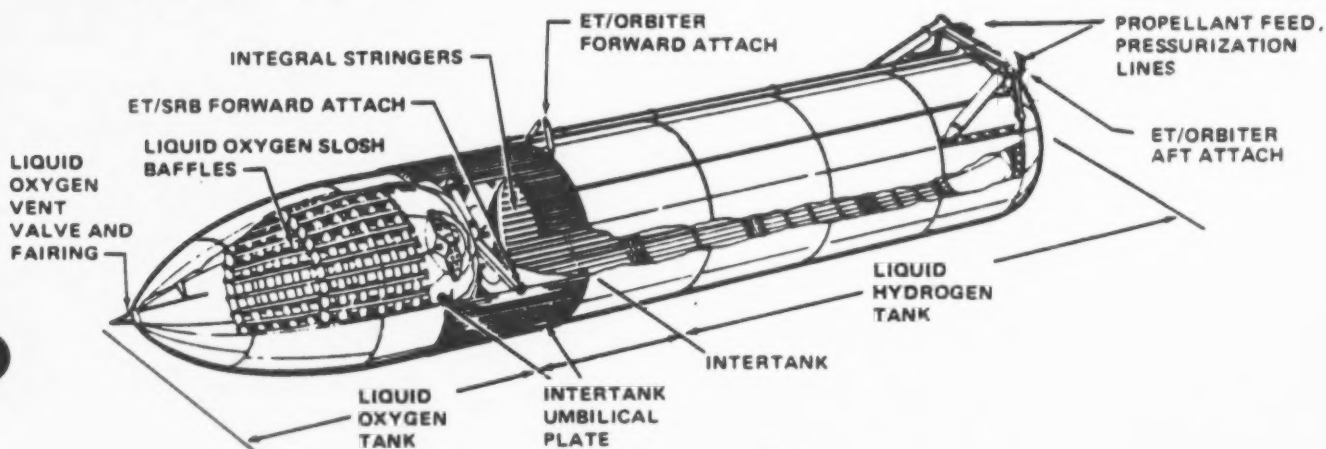
Orbiter



Solid Rocket Booster



External Tank

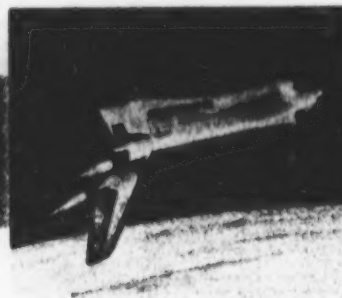




Space Transportation System

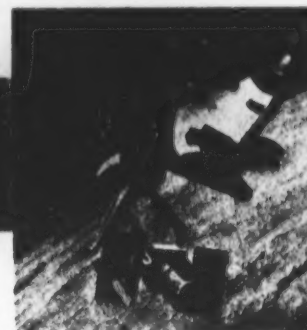
MAIN ENGINE CUTOFF, EXTERNAL TANK SEPARATION

Altitude: 50 nmi
(68 miles); velocity: 7790
mps (25,581 fps, 17,440
mph) about 8 minutes
after launch (just before
orbit insertion)



ORBIT INSERTION AND CIRCULARIZATION

Altitude varies
according to
mission



ORBITAL OPERATIONS

Mission from 7 to 30 days;
100 to 600 nmi (115 to
690 miles) orbits; 7743
mps (25,445 fps, 17,321
mph)

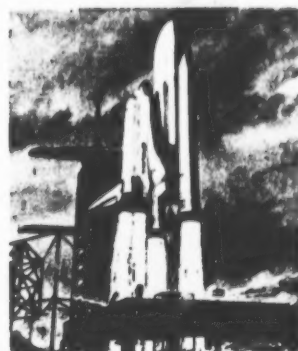


SRB SEPARATION

Altitude: 24 nmi (28 miles);
velocity: 1383 mps
(4,538 fps, 3,094 mph)
2 minutes after launch

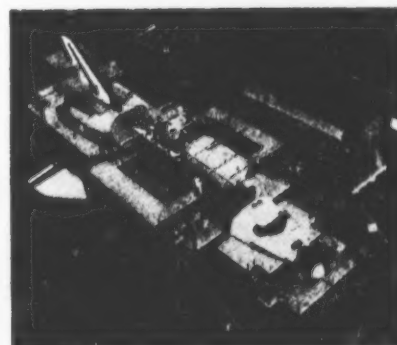
DEORBIT

Velocity decreased nominal
91 mps (300 fps, 204 mph)
from earth orbit operations

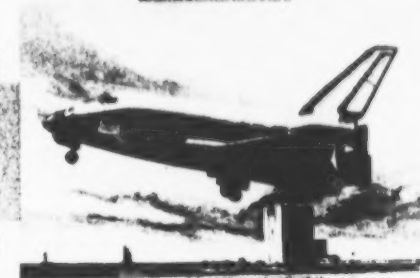


LAUNCH

Maximum dynamic
pressure at 10,241 meters
(33,600 ft); about 60
seconds after launch



MAINTENANCE Two-week turnaround (14 days—160 hours)



LANDING

Touchdown speed
184 to 196 knots
(213 to 226 mph)

Shuttle Mission Profile

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In the BOOK SECTION which follows, the suggested reading or usage level of each item is designated by code letters as follows:

(P) primary-grades 1-3; (I) intermediate-grades 4-6; (U) upper-grades 7-8; (S) secondary-grades 9-12; and (A) adult or college level. Most books that are of general interest to the public at the adult level are also listed for secondary unless they require a background more appropriate strictly to the adult level.

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 Jean F. Blashfield
 NASA 1982

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F. Aeronautics

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G. Energy

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H. Space and the Humanities

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I. Aerospace Education

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3. NASA Educational Services

NASA's educational programs serve the teacher, the student, the school, and the community. Information about the programs and services, including lists of *NASA Publications* and *NASA Films*, is available from the Educational Services Office at the NASA Centers that serve specific geographic areas. Special resource centers, which make professional curriculum materials available to teachers, have been established at most of the NASA Centers. Where to write for services:

NASA Ames Research Center

Moffett Field, California 94035

Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

NASA Goddard Space Flight Center

Greenbelt, Maryland 20771

Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

NASA Lyndon B. Johnson Space Center

Houston, Texas 77058

Colorado, Kansas, Nebraska, New Mexico, N. Dakota, Oklahoma, S. Dakota, Texas

NASA John F. Kennedy Space Center

Kennedy Space Center, Florida 32899

Florida, Georgia, Puerto Rico, Virgin Islands

NASA Langley Research Center

Hampton, Virginia 23665

Kentucky, N. Carolina, S. Carolina, Virginia, West Virginia

NASA Lewis Research Center

21000 Brookpark Road, Cleveland, Ohio 44135

Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

NASA George C. Marshall Space Flight Center

Marshall Space Flight Center, Alabama 35812

Alabama, Arkansas, Iowa, Louisiana, Mississippi, Missouri, Tennessee

FILMS & FILMSTRIPS

WEATHER

1. A New Look at an Old Planet. HQ 178 - 1969 - NASA
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3. Lightning and Thunder. Coronet Films
4. Our Weather. Encyclopedia Britanica Ed.
5. Portrait of Earth HQ 299- 1981-NASA (Weather Satellites)
6. The Atmosphere. FAA
7. Weather for Beginners. Coronet Films
8. The Weather Watchers. HQa 290-1977-NASA
9. How to Forecast the Weather. Society for Visual Educ. 1967.
A set of 6 color filmstrips. Subjects are:

Air Masses and Weather Fronts
Winds Around the World
Humidity and How it Affects Us
How to Forecast the Weather
Moisture and Precipitation in the Air
Weather Changes and Their Causes.

FACTS OF FLIGHT

10. Aircraft Their Power and Control. (6 filmstrips) Scott Educ.
11. Airplanes: Principles of Flight. Coronet
12. Discover Flying: What Makes an Airplane Fly? Beech Aircraft Co.
13. Come On Up. Champion Spark Plug Co.
14. How Airplanes Fly. FAA
15. Man in Flight. U.S. Airforce

THINGS THAT FLY

16. Aircraft Oddities. NASA
17. Flying Floats. FAA

18. Man in Flight. Walt Disney Films
19. No Runway Needed. Shell Oil Co. (Helicopters)
20. The Blimps: Clearly Identified Flying Objects Goodyear Tire Co.
21. The Science of Flight G.C. Burns Films
22. The Wind is Right. Champion Spark Plug Co. (A Michigan H.S. class builds an airplane)
23. To Fly. Modern Talking Picture Service (A very fine film)

NAVIGATION

24. Area Navigation. FAA
25. Flight 52. FAA. (Behind the scenes at air traffic control)
26. Radar Contact FAA
27. The Story of Navigation. U.S. Air Force

THE AIRPORT

28. Airport in the Jet Age. Encyclopedia Britanica Films
29. An Airplane Trip by Jet. Encyclopedia Britanica Films
30. Dulles International Airport-Port of the Future. FAA
31. 55 To Get Ready. (The people who ready an aircraft for flight)
Agency for Instructional Television

THE EARTH AND THE SOLAR SYSTEM

32. Journey Into Light. (The Story of Kitt Peak National Observatory at Kitt Peak, Arizona) Kitt Peak, Tucson, Arizona
33. Earth-Sun Relationship. HQ 235-NASA
34. The Earth: Its Atmosphere. Corcoran
35. Universe. NASA
36. Universe and I Agency for Public Television
37. Our Solar System. NASA
38. The Solar System. Agency for Public Television

39. Who's Out There? NASA

ROCKETS AND MISSILES

40. About Our Missiles. U.S. Air Force
41. Common Carrier For Space-Titan III. U.S. Air Force
42. Research Project X-15. NASA
43. Road to the Stars. (History of the Rocket) USAF
44. Rocket Launches From Cape Kennedy. (Apollo Project) NASA
45. The Missile Navy. Sperry Univac
46. X-15. USAF

SATELLITES, SPACECRAFT AND SPACE TRAVEL

47. Why Space? USAF
48. Wonders of Weightlessness USAF
49. The Eagle Has Landed USAF
50. Space Navigation. USAF
51. Debrief: Apollo 8. NASA (One of a series on the Apollo flights)
52. Eagle Has Landed; The Flight of Apollo 11. NASA
53. The Time of Apollo NASA
54. Apollo-Soyuz. NASA
55. The Flight of Faith 7. (The last Mercury flight) NASA
56. Legacy of Gemini NASA
57. Space in the 70's-Space Down to Earth. (Earth applications) NASA
58. The Age of Space Transportation. NASA
59. The First Space Walk. NASA
60. Lunar Module Descent to the Moon. NASA
61. First Steps to the Stars. (early space flights) McDonnell Douglas

62. The Lighthouse That Never Fails. (excellent comedy on space flight) Sperry Univac
63. Hail Columbia. (First Shuttle Flight). NASA
64. Meteorology From Space. NASA (filmstrip)
65. How an Astronaut Lives in Space. Filmstrip House
66. Man in Space. (Walt Disney) Encyclopedia Britannica Films

Many other films are available from NASA and other suppliers. Consult a NASA film catalog or the NASA Teacher Resource Center in your service area.

COMMERCIAL TEXTBOOKS

Don't overlook these resources in your classroom. An effort was made to include lessons in this guide which correspond to concepts taught in texts currently being used in the United States. The following is a list of the texts surveyed.

Cambridge Work-a-Text, EARTH SCIENCE
Cambridge Book Company
New York, NY

EARTH SCIENCE, LIFE SCIENCE, PHYSICAL SCIENCE
Scott, Foresman and Company
1900 East Lake Avenue
Glenview, IL 60025

EXPLORING PHYSICAL SCIENCE
Allyn and Bacon, Inc.
Boston, MA

FOCUS ON LIFE, PHYSICAL, EARTH SCIENCE
Charles E. Merrill Publishing Co.
Columbus, Ohio

HOLT EARTH, LIFE, PHYSICAL SCIENCE,
HOLT GENERAL SCIENCE
Holt, Rinehart and Winston Publishers
New York, NY

11S, PHYSICAL SCIENCE, LIFE SCIENCE
Prentice Hall Inc.
Engelwood Cliffs, NJ

INVESTIGATING THE EARTH
Houghton Mifflin Company
Boston, MA

NUFFIELD PHYSICS and COMBINED SCIENCE
Nuffield Foundation
Longman Group Limited
London, England GB

OUR PLANET IN SPACE The Earth Sciences
Harper & Row, Publishers
New York, NY

PATHWAYS IN SCIENCE, PHYSICS, CHEMISTRY, EARTH SCIENCE
Globe Book Company
New York, NY

PHYSICAL SCIENCE Principals and Applications
Wm. C. Brown Company Publishers
Dubuque, Iowa

PRINCIPLES OF SCIENCE-book 1 & 2
Charles E. Merrill Publishing Co.
Columbus, Ohio

PROBING THE NATURAL WORLD
Intermediate Science Curriculum Study
Silver Burdett
Morristown, NJ

THE PROJECT PHYSICS COURSE Handbook
Holt, Rinehart and Winston
New York, NY

TEACHER RESOURCE BOOKS

TEACHING SCIENCE BY INQUIRY IN THE SECONDARY SCHOOL
Charles E. Merrill Publishing Company
Columbus, Ohio

COMPUTER SOFTWARE

The following are computer courseware programs which teach concepts related to aviation and space. The programs are listed only as a service to the users of this guide and no endorsement is intended or implied. The authors suggest you try any computer software before you buy. The list is most certainly not the definitive list of aerospace courseware but a collection of easily found programs which are readily available to teachers.

CLOSE EARTH ORBIT

Players control a fleet of US space satellites as they watch the control panels and telemetry screen simulated on the monitor.
Apple III 3.3 DOS, 48K.

DISCOVER

A recent space probe has just brought back several new life forms. It is your job to keep them alive as long as possible. Students are in the role of scientist and must problem solve to be successful.
Apple II or IIe with 48k, with Applesoft and DOS 3.3
from The Micro Center

EARTHQUAKES

Students plot latitude and longitude coordinates on a world map.
Apple II
from Cambridge Development Laboratory

FLIGHT SIMULATOR

Fly an airplane VFR or IFR from takeoff to landing. Complete panel and horizon visuals.
Apple II plus
from Programmers Software

LATITUDE/LONGITUDE

Requires students to identify geographical coordinates in 10 random problems. Produced by Robbinsdale Schools, MN.
Pet 8k - from Sunburst

LAWS OF MOTION

Students can discover and test for themselves laws of motion. Experiments in free fall, inclined plane and acceleration. Society for Visual Education (SVE), Chicago, IL.
Apple II 3.3 DOS, 48K or TRS 80 I or III with 32K.

MECC SCIENCE VOLUME 4

URSA is contained in this package and acquaints students with stars and major northern constellations. SOLAR DISTANCE deals with concepts of speed of light, distance and names of planets.
Apple requires 32k - Atari 16k - Available from Sunburst

RENDEZVOUS-A SPACE SHUTTLE FLIGHT SIMULATION

A highly recommended program by Electronic Learning. Launch, orbit and dock a shuttle with a space station. Bridges the gap between games and learning programs. Requires a good deal of knowledge.

Diskette for 48k Apple II with Applesoft and DOS 3.3 or Apple IIe from The Micro Center

SOLAR HOUSE SIMULATOR

Simulation of solar energy system using fixed collectors.

TRS-80 I & III, Apple II plus, IBM P.C.

from Cambridge Development Laboratory

SPACE STATION

Develops understandings of displacement, speed and acceleration.

Apple II with DOS 3.3, 48k and game paddles.

from Cambridge Development Laboratory

WORLD CLOCK

Shows the sun's effect on the earth for one year. Time zones, seasons climate and sun's relationship to the earth are covered.

Apple II

Cambridge Development Laboratory

ADDRESSES OF AGENCIES SUPPLYING MEDIA

GOVERNMENT FILM AGENCIES

1. United States Air Force

Central Audio-Visual Library
Aerospace Audiovisual Service
Norton AFB, California 92409

Films free on request. Request films three weeks in advance.
Catalog available from the U.S. Gov't printing office.

2. Federal Aviation Administration (FAA)

Film Library, AAC-44E
Federal Aviation Administration
P.O. Box 25082
Oklahoma City, Oklahoma 73125

Films available free. Request two weeks in advance. Two
films per week may be ordered. Write for catalog.

3. NASA - Lewis Research Center

Teacher Information Center
Mail Stop 8-1
21000 Brookpark Road
Cleveland, Ohio 44135 (216) 433-4000 Ext. 6110

Free loan. Phone or write for current catalog and availability
NASA will copy films on to video format at your request for the
cost of materials only.

4. Michigan Aeronautics Commission

Capital City Airport
Lansing, Michigan 48906

Write for film list. Free loan.

NON-GOVERNMENT FILM AGENCIES

1. Agency for Instructional Television
Box 1111 West 17th Street
Bloomington, IN 47401
2. American Association of Physics Teachers
Graduate Physics Building
SUNY at Stony Brook
Stony Brook, NY 11794
3. Association-Sterling Films
866 Third Avenue
New York, NY 10022
4. Beech Aircraft Corporation
Wichita, KS 67201
5. Business Aircraft Association
425 13th St., N.W., Suite 401
Washington, DC 20004
6. Champion Spark Plug Company
Film Section, Department M
P.O. Box 910
Toledo, OH 43661
7. Coronet Films
65 E. South Walter Street
Coronet Building
Chicago, IL 60601
8. Eastern Airlines, Inc.
Film Library
International Airport Branch
Miami, FL 33148
9. Encyclopedia Britannica Educational Corporation
1150 Wilmette Avenue
Wilmette, IL 60091

10. General Aviation Manufacturers Association
Suite 1200-A, 1025 Connecticut Avenue, N.W.
Washington, DC 20035
11. Goodyear Tire and Rubber Company
Public Relations Film Library
1144 East Market Street
Akron, OH 44316
12. G.C. Burns Film Presentation
17160 Tulsa Street
Grenada Hills, CA 91340
13. Kitt Peak National Observatory
Films, Public Information Office
P.O. Box 26732
Tucson, AZ 85726
14. Lockheed-Georgia Company
Motion Picture Film Library
Zone 30, B-2 Building
Marietta, GA 30063
15. McDonnell Douglas Corporation
2525 Ocean Park Blvd.
Film Distribution and Promotion
Santa Monica, CA 90405
16. Modern Talking Picture Service, Inc.
21421 Hilltop St., Suite 23
P.O. Box 5022
Southfield, MI 48037
17. Shell Film Library
1433 Sadlier Circle W. Drive
Indianapolis, IN 46239
18. Society for Visual Education (Filmstrips)
Division of General Precision Equipment Corp.
1345 Diversey Parkway
Chicago, IL 60614

19. Sperry Univac
Advertising and Sales Promotion
P.O. Box 500
Blue Bell, PA 19422

20. Walt Disney Productions
Education Films Division
350 Beuna Vista Avenue
Burbank, CA 91503

21. Western Airlines
P.O. Box 92005
World Way Postal Center
Los Angeles, CA 90009

GOVERNMENT PUBLICATIONS AGENCIES

1. Civil Air Patrol (CAP)

National Headquarters
Maxwell AFB, AL 36112

Michigan Wing (CAP)
30712 Michigan Ave.
Building A
Westland, MI 48184
(313) 721-6210

2. Federal Aviation Administration (FAA)

FAA Headquarters
Public Inquiry Center, APA-430
800 Independence Avenue. S.W.
Washington, D.C. 20591
(202) 426-8058/8059

3. National Aeronautics and Space Administration (NASA)

NASA Headquarters
Community and Education Services Branch
LFG-11
Washington, D.C. 20546

NASA Lewis Research Center
Teacher Resource Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-4000 Ext. 6110

4. State Aviation Department

Michigan State Aeronautics Commission
Capital City Airport
Lansing, MI 48906
(517) 373-1834

5. United States Government Printing Office

Gov't Printing Office
710 North Capital St.
Washington, DC 20230
(202) 275-2091

Patrick V. McNamara Federal Building
Suite 160
477 Michigan Avenue
Detroit, MI 48226
(313) 226-7816

NON-GOVERNMENT PUBLICATIONS AGENCIES

1. Academy of Model Aeronautics
1810 Samuel Morse Drive
Reston, VA 22090
2. Aero Products Research, Inc.
11201 Hindry Avenue
Los Angeles, CA 90045
3. Aerospace Education Association
1910 Association Drive
Reston, VA 22091
(Formerly the American Society for Aerospace Ed.)

The only professional education organization in the U.S. devoted to the promotion of aviation and aerospace educational at all levels of learning. The Society publishes AVIATION/SPACE The Journal of Aerospace Education. They also publish the most complete resource directory of aerospace education available.

4. AVI Astroport
Mineral Point, WI 53565

5. Air Transport Association of America
Public Relations Department
1709 New York Avenue, N.W.
Washington, DC 20006
6. Alabama Space and Rocket Center
Tranquility Base
Huntsville, AL 35807
(Request free teaching aids)
7. J. T. Becker Associates
799 Roosevelt Road
Glen Ellyn, IL 60137
8. Beech Aircraft Corporation
Wichita, KS 67201
9. Estes Industries
Penrose, CO 81240
(model rockets and education materials)
10. Experimental Aircraft Association
Wittman Field
Oshkosh, WI 54901
11. Flying Tiger Line
7401 World Way West
P.O. Box 92935
Los Angeles, CA 90009
12. General Aviation Manufacturers Association
Suite 1215
1025 Connecticut Avenue, N.W.
Washington, DC 20036
13. Hamilton Standard
Windsor Locks, CT 06096

14. Jeppesen Sanderson
Education Division
8025 E. 40th Avenue
Denver, CO 80207
15. Kitt Peak National Observatory
Public Information Office
P.O. Box 26732
Tucson, AZ 85726
16. Lockheed, Lockheed-Georgia Company
86 South Cobb Drive
Marietta, GA 30063
17. Los Angeles Department of Airports
No. 1 World Way
Los Angeles, CA 90009
Attention: Public Relations Department
18. National Space Institute
P.O. Box 296
Amherst, WI 54406
19. Ninety-Nines International Headquarters
P.O. Box 59964
Will Rogers World Airport
Oklahoma City, OK 73159
20. The Planetary Society
110 S. Euclid Avenue
Pasadena, CA 9110118.
21. Young Readers Press
1 West 39th Street
New York, NY 10018

MICHIGAN

RESOURCE CENTERS

The following are repositories of information related to Aerospace Education. Each should be contacted individually for information on loan policies and contents of current collections.

• **Aviation and Space Center**

Dr. David C. Housel, Director
Oakland University
Rochester, MI 48063 (313) 377-2485

Central Michigan University

Dr. John Bergeson, Director
Instructional Materials Center
Rowe Hall
Mt. Pleasant, MI 48858

Macomb Community College

Prof. Earl Hickey
Warren, MI 48000

Michigan Space Center

Jackson Community College
2111 Emmons Road
Jackson, MI 49201 (517) 787-4425

Western Michigan University

Prof. Herman Linder
Kalamazoo, MI 49001

NASA Lewis Research Center

21000 Brookpark Road
Cleveland, OH 44135 (216) 433-4000 ext. 6110

MICHIGAN RESOURCE PERSONS

The following people from the state may be contacted by teachers for assistance related to aerospace education. Teachers are encouraged to contact those persons in their area in order to gain further information on the area of expertise of each individual.

Anglin, Mary, 301 S. Meade, Flint, MI 48503, (0) 313/235-0681;
313/238-2978

Armstrong, Dick, 22912 Canterbury Dr., St. Clair Shores, MI 48080;
313/776-7587

Beers, June, 1989 Mapleridge Rd., Rochester, MI 48063; 313/583-5435

Bennett, Esther, 46 Williams, Pontiac, MI 48053; 313/338-3376;
(0) 313/666-3555

Bergeson, Dr. John, Central Michigan University, Ronan Hall, Mt. Pleasant,
MI 48859; (0) 517/774-3549 AECM

Berz, Ted, 46284 Johnathan Circle, Utica, MI 48087; 313/739-0632

Binsfield, Addie, 3843 Island Park Dr., Drayton Plains, MI 48020;
313/674-4453

Bobrowicz, Dot, 34473 Grove Dr., Livonia, MI 48154; 313/591-1329

Bodrie, Shirley, 86 Chestnut, River Rouge, MI 48218; 313/843-8870

Boehmer, Capt. Curtis, Civil Air Patrol, 1445 Lakeside, P.O. Box 45,
Harbor Beach, MI 48441

Bonnell, Robert, Teacher, 6th Grade, Lincoln Park School, 3426 Leon,
Muskegon, MI 49441; (0) 616/755-1257; 616/798-2493 AECM

Brandi, Fran, 31425 Myrna, Livonia, MI 48154; 313/522-4360

Broome, Judith, 797 Lincoln Rd., Grosse Pointe, MI 48230; 313/882-
4664; (0) 876-6126

Brown, John, 21975 Leyte, Farmington Hills, MI 48024; 313/474-4816

Bytwerk, Betty, 15780 Bittersweet, Spring Lake, MI 49456; 616/842-2646

Chamberlain, Kay, 220 N. Kinney, Mt. Pleasant, MI 48858; 517/773-5433

Clark, Ruth, 4931 Jewell, Howell, MI 48843; 517/546-0882

Collier, Dr. Calhoun, Retired Professor, Michigan State University, 612 Oakwood Dr., East Lansing, MI 48823; 517/332-2087 AECM

Conrad, Catherine Bennett ("Tip"), 2322 El Dorado S.E., Grand Rapids, MI 49506; (0) 364-9485, 616/942-9843

Cook, Barbara, 651 E. Joy Rd., Ann Arbor, MI 48105; 313/769-2432

Cook, Lynn, 140 W. Brown St., Tecumseh, MI 49286; (0) 517/423-7427; 517/423-4825

Creason, Mary, Ass't Administrator, Safety & Services, Michigan Aeronautics Commission, Capital City Airport, Lansing, MI 48906; (0) 517/373-8532; 616/842-9658 AECM

Crook, Betty, 992 Lakeview, R#3, Gaylord, MI 49735; 517/732-9171 or 732-6484

Debring, Carl & Marti, 17591 Glenwood, Lathrup Village, MI 48076; 313/557-5567

DeForest, Lynn, 10519 Turnerwood Dr., Fenton, MI 48430; 517/546-2160

Del Giorno, Velma B., 10307 Blue Lake Rd., Mecosta, MI 49332; 616/972-7674

Dellinger, Rick, Director, Aviation Technology, Jackson Community College, 2111 Emmons Rd., Jackson, MI 49201; 517/787-0800

Devlin, Shiela, Birmingham, MI; 313/851-1963

Disler, Edith A., 6930 W. Dartmoor, W. Bloomfield, MI 48033; 313/855-2135

Doyle, Tim, P.O. Box 414, Ypsilanti, MI; 313/434-3600

Druskins, Linda, 701 Columbia, Midland, MI 48640; 517/631-4530

Dyer, Susan, 1214 E. Fifth St., Royal Oak, MI 48067; 313/543-4615

Eiseman, Ruth M., 627 Piccadilly, Kalamazoo, MI 49007; 616/382-1149

Emery, Sister Marie T., 3142 Lake Lansing Road, East Lansing, MI 48823;
517/353-1790

Evans, Elaine, 760 Rachelle, Union Lake, MI 48045; 313/363-7902

Featherston, Frederick, 2955 Lynn, Pontiac, MI 48054; 313/666-2135

Fisher, Harold, Special Projects Director, Muskegon Area Intermediate
School District; 630 Harvey, Muskegon, MI 49442; (0) 616/777-2637;
842-4317 AECM

Flanagan, Kirt, 428 La Prairie, Ferndale, MI 48820; 313/852-6834

Fleming, Thea, 3854 Chamberlain S.E., Grand Rapids, MI 49508; 616/241-3854

French, Tim, 1613 Vernon St., Trenton, MI 48183; 313/675-9075

Gardanier, Mary W., 1828 Miles Avenue, Kalamazoo, MI 49001; (0) 616/343-
1261, 616/344-0563

Greenlee, Eloise, Greenlee Printing Company, 423 Pine St., Calumet, MI 49913;
616/227-1300 AECM

Hecksel, Warren-Nancy, 2611 Greenway, Royal Oak, MI 48073; 313/576-0463

Hemingway Ilene, 15230 Lakewide Dr., Plymouth, MI 48170; 313/420-2973

Higgins, Leah, 4921 Crooks Rd., Apt. #N8, Royal Oak, MI 48073

Hoffman, Betsy Kay, 3297 E. Greenfield Court, Bay City, MI; (0) 754-2471;
684-4858

Housel, Dr. David, Science Professor, Oakland University, Rochester, MI 48063; (0) 313/377-3079, 348-7115 AECM

Housel, Doreen, Graphic Artist/Teacher, 19923 Schoolhouse Court, Northville, MI 48167; 313/348-7115 AECM

Jubb, Dr. Wanda, Health Education Specialist, Michigan Department of Education, P.O. Box 30008, Lansing, MI 48909; (0) 517/373-1484, 339-3952 AECM

Kimball, Harold, 1213 Woodhaven Dr., Union Lake, MI 48085

King, Janet, 8670 Judston, Romulus, MI 48174; 313/721-8935

Kirchner, Ronald, Teledyne-Continental, Muskegon Co. Airport, Muskegon, MI 49441; (0) 616/724-2031, 846-8847

Kniecik. Jim & Karen, 1369 Kentworth, Clawson, MI 48017; 313/288-0638

Kreeger, Natalie Ruth, Director of Services, Fowlerville Public Schools, Fowlerville, MI 48836; (0) 223-8754, 223-9702 AECM

Kufchock, Liane, 8662 Edna, Warren, MI; 48093; 313/573-9373

Littler, Marie, 28838 Aranel, Farmington Hills, MI; 313/553-4963

Martlew, Glenda, 1205 Kensington, Flint, MI 48503; 313/238-6882

McCombs, Joan Esther, 12936 Vergennes, Lowell, MI 49331; 616/897-5785

McJilton, Shirley G., 2908 Whittier, Kalamazoo, MI 49001; (0) 616/385-2012, 349-6032

McKay, Sammy, 9191 S. Dixie Hwy., Grand Blanc, MI 48439; 313/694-6116

McLaughlin, Renate, 1432 Duffield Rd., Lennon, MI 48449; (0) 313/762-3244, 621-3402

Myers, Mrs. Allen, 4401 Macon Rd., Tecumseh, MI 49286; 517/423-7629

Millar, Bernie, 35729 Elm St., Wayne, MI 48184; 313/722-1893

Mincemoyer, Nancy, Science Specialist, Michigan Department of Education,
P.O. Box 30008, Lansing, MI 48909; (0) 373-8793, 337-7285 AECM

Mitchell, Bev, 1519 Bramblewood Rd., Holly, MI 48442

Moorhatch, Pat, 26839 Thomas, Warren, MI 48091; 313/756-4129

Morganroth, Fred & Janice, 4000 Town Center Ste. 555, Southfield, MI
48075; 313/357-5600

Napierla, Margaret, 2802 W. Genesee, Saginaw, MI 48602; 517/792-1150

Nicholsen, Valerie, 4850 Lodewyk, Detroit, MI 48224

Ojala, Claire, 26695 Simone, Dearborn Heights, MI 48127; 313/274-5674

Palka, Ed, 3358 Westwind Dr., Detroit, MI

Pailthorpe, Bill & June, 9536 Fenhill Dr., Grand Blanc, MI 48439; 313/
655-4019

Paulson, Col. Robert W., Wing Commander, Civil Air Patrol, 236 No. Lafayette,
Dearborn, MI 48128; 313/274-3975, 517/828-5277 AECM

Redmond, Dr. Lois, Professor, Central Michigan University, Ronan Hall,
Mt. Pleasant, MI 48859; (0) 517/774-3975, 517/828-5277 AECM

Roach, John, 746 Bedford Rd., Grosse Pointe Park, MI 48230; 313/821-4868

Ross, Dolly, 138 Hillcrest Dr., Hillsdale, MI 49242; (0) 517/437-4180,
437-4131

Ruth, Babe, 14645 Airport Rd., Lansing, MI 48906; 517/321/2278

Slahan, Elizabeth, P.O. Box 394, Perrysburg, Ohio 43551; 419/874/3429

Smith, Eloise M., 20710 Rambling Rd., Kalamazoo, MI 49009; 616/381-5945

Snyder, Lillian, 9990 Beaconsfield, Detroit, MI 48224; 313/822-8916,
526-0846

Sowle, James, Industrial Education Instructor, Forest Hills Central High School, 5901 Hall St. S.E., Grand Rapids, MI 49507; (O) 616/676-1245; 676-2202 AECM

Steadman, Bea, 1172 Knoll Crest, Traverse City, MI 49684; 616/947-2567

Stears, Masie R., 3999 East E. Avenue, Kalamazoo, MI 49004; 616/385-3839

Stevenson, Lois, National Weather Service, Muskegon County Airport, Muskegon, MI 48441; (O) 616/798-1380; 744-2937

Suave, David, Maple Grove School, Lansing, MI 517/374-4712

Sutherland, Gini, 1980 Redding Road, Birmingham, MI 48009; 313/642-8756

Swenson, Dr. Raymond, Director, Aviation & Transportation Department, Andrews University, Berrien Springs, MI 49104; (O) 616/471-3547 AECM

Thomas, Sylvia, 8900 E. Jefferson #515, Detroit, MI 58214; 313/823-5506

Toboldt, Jay C., 31531 Evergreen, Birmingham, MI 48009; 313/642-7437

Vandersloot, Jeanne Elaine, 127 Campbell Place, Grand Rapids, MI 49503; 616/454-5836

Van Malsen, Wesley, Lansing Community College, Capital City Airport, Lansing, MI 58906

Vargo, Katherine, 6091 King Arthur Dr., Swartz Creek, MI 48473; (O) 313/372-6520

Wagner, John L., Aerospace Education Coordinator, Michigan Aeronautics Commission, Capital City Airport, Lansing, MI 48906; (O) 517/373-3871 AECM

Walter, Larry, Grand Haven Jr. High School, 1400 S. Griffin, Grand Haven, MI 49417; (O) 616/842-5010; 842-3246 AECM

Walters, Ron and Nancy, 2522 Woodland, Royal Oak, MI 313/435-0441

Whyte, Suzanne, Pine Beach Road, R#3, Gaylord, MI 49735; 517/732-1105;
(0) 732-2511

Wolf, Esther Bennett, 9144 Steep Hollow, Pontiac, MI 48054; (0) 313/
342-2014; 698-2004

Wood, Phyllis, 15056 Seneca, Redford, MI 48239; 313/255-5917

Wright, Shirley, 64 Hawthorne, Grosse Pointe, MI 48225; 313/884-7754

*AECM denotes Aerospace Education Council of Michigan members

MICHIGAN 'SPACEMEN'

Several persons with Michigan connections have been or are involved with the U.S. space program. The following is a list of some of them.

DOUGLAS AHERNS

Mr. Aherns, a 1947 graduate of Jackson High School, was the General Dynamics Astronautics Leading Propulsion Engineer for Complex 14, Mercury Launching Site at Cape Kennedy. He was also connected with the Gemini series. It was his job to erect the missile, check out the engineering before the flight and make sure everything was "A-OK" during the initial lift-off period.

ASTRONAUT NAVY CAPTAIN ALAN BEAN

Astronaut Bean, whose parents grew up in Jackson (he still has relatives there) was a member of the backup crew of Gemini 10 and was designated Lunar Module Pilot for Apollo 12, during which time he participated in two lunar walks.

ASTRONAUT ROGER B. CHAFFEE

Born February 15, 1935, in Grand Rapids, Michigan, where his parents Mr. and Mrs. Donald Chaffee reside. Chaffee, now deceased, graduated from Central High School, Grand Rapids and received a Bachelor of Science Degree in Aeronautical Engineering from Purdue University in 1957. He was awarded the Navy Air Medal. He died in the Apollo spacecraft fire which also killed Gus Grissom and Edward White on January 27, 1967.

ASTRONAUT CAPT. THEODORE C. FREEMAN (USAF)

Born February 18, 1930, in Edwards, California. In 1960, he received a Master of Science Degree in Aeronautical Engineering from the University of Michigan. Astronaut Freeman was a member of the American Institute of Aeronautics and Astronautics. He died in the crash of a T-38 aircraft on October 31, 1964 at Ellington Air Force Base, Houston, Texas.

NAVY CAPT. ROBERT FREITAG

Born in Jackson, Michigan in 1920. He has been administrator of NASA launch bases. He has also been Special Assistant to the Associate Administrator for Manned Space Flight where he was instrumental in working out an agreement between NASA and the European Space Research Organization

for the sharing of costs of space ventures. He now is in charge of advanced mission programs beyond 1980. Captain Freitag has degrees from Jackson Junior College, University of Michigan and Michigan Institute of Technology. He is credited with being one of the fathers of the Polaris missile program.

ASTRONAUT FRED WALLACE HAISE, JR.

Born November 14, 1933, in Biloxi, Mississippi. He received an Honorary Doctorate of Science from Western Michigan University in 1970. He has received numerous awards and has published several papers on aircraft. He became an astronaut in 1966 and served as backup Lunar Module Pilot for three Apollo VIII and XI missions. He was Lunar Module Pilot for Apollo XIII. He was later designated to serve as backup spacecraft commander for the Apollo XVI mission.

ASTRONAUT KARL G. HENIZE PhD.

Born October 17, 1926 in Cincinnati, Ohio. He earned a PhD in Astronomy at the University of Michigan in 1954. He is married to Caroline Weber of Bay City, Michigan. Dr. Henize was an astronomer for the University of Michigan Observatory in Bloemfontein, Union of South Africa from 1948 to 1951. He was selected as a Scientist-Astronaut by NASA in 1967. He was a member of the Apollo XV mission support crew and served in that capacity for the Skylab missions.

ASTRONAUT JAMES BENSON IRWIN

Born March 17, 1930 in Pittsburgh, Pennsylvania. He received degrees in Aeronautical Engineering, Instrument Engineering and an Honorary Doctorate of Astronautical Science from the University of Michigan. Irwin served as Lunar Module Pilot for Apollo XV. He and David Scott used "Rover-1" to collect almost 160 lbs. of lunar surface material.

ASTRONAUT JACK ROBERT LOUSMA Lt. Colonel, USMC

Born February 29, 1936 in Grand Rapids, Michigan. His father, Mr. Jacob Lousma, lives in Jackson, Michigan. He attended Jackson High School and Ann Arbor High School and received a Bachelor of Science Degree from the University of Michigan in 1959. He is married to Gratia Kay Smeltzer of Ann Arbor. Lousma served as a member of the astronaut support crews for Apollo's IX, X and XIII. He was pilot for Skylab-3 from July 28 to September 25, 1973. Col. Lousma was designated backup docking module pilot for Apollo-Soyuz Test Project which flew in July of 1975. He was pilot for Shuttle 3 in 1982.

ASTRONAUT JAMES A. MC DIVITT Brigadier General USAF

Born June 10, 1929 in Chicago, Illinois. He graduated from Kalamazoo Central High School, Kalamazoo, Michigan and received a Bachelor of Science in Aeronautical Engineering from the University of Michigan in 1959. He was awarded an Honorary Doctorate in Astronautical Science from the U of M in 1965. He was command pilot for Gemini 4, commander of Apollo IX and eventually became manager for the entire Apollo program. As a civilian, he served as Senior Vice President at Consumers Power Company in Jackson, Michigan.

ASTRONAUT EDGAR MITCHELL USN

Born September 17, 1930 in Herford, Texas. He married Louise Elizabeth Randall of Muskegon, Michigan. He as a member of the support crew for Apollo IX and a backup lunar pilot for Apollo X. He landed the Lunar Module "Antares" on the Fra Mauro region of the moon during the Apollo XIV mission and assisted Alan Shepard in collecting and returning almost 100 lbs. of lunar material to the earth. He was later designated as backup lunar pilot for Apollo XVI.

ASTRONAUT CAPTAIN RICHARD POLLARD

Astronaut Pollard was a member of the space surgeon team in charge of medical operations for the Apollo program. He was instrumental in selecting the second group of astronauts for the space program during the Gemini mission phase. He is a graduate of Albion College and the University of Michigan Medical School.

ASTRONAUT DAVID R. SCOTT USAF

Born June 6, 1932 in San Antonio, Texas. He was awarded an Honorary Doctorate in Astronautical Sciences from the University of Michigan in 1971. He flew with Neil Armstrong in Gemini 8, was command module pilot on Apollo IX and was spacecraft commander on Apollo XV. He has logged one of the highest records for hours flown in space.

ASTRONAUT BREWSTER SHAW USAF

Born May 16, 1945 in Cass City, Michigan. He graduated from Cass City High School in 1963. He earned a Bachelor of Science and Masters Degrees from the University of Wisconsin. He was a highly decorated pilot while in the Air Force earning the Distinguished Flying Cross as well as many other medals and honors. He was a Distiquished Graduate at the Officers Training School and the Air Force Test Pilots School. He logged over 3000 hours of flight time in 30 types of aircraft while in the Air

Force. He became an astronaut in 1979 and flew as pilot on Shuttle 9.

ASTRONAUT DONALD K. SLAYTON

Born March 1, 1924 in Sparta, Wisconsin. He received a Honorary Doctorate in Engineering from Michigan Technological University in 1965. He was named as one of the original Mercury astronauts in 1959 and eventually served as Coordinator of Astronaut Activities. He was later Director of Flight Crew Operations. In 1975 he was Designated Command Pilot for the Apollo-Soyuz program.

ASTRONAUT JOHN LEONARD SWIGERT, JR.

Born August 30, 1931 in Denver, Colorado. He received an Honorary Doctorate of Science from Western Michigan University in 1970. He was a member of the astronaut support crew for Apollo VII and flew on Apollo XIII in 1970 replacing astronaut Thomas Mattingly as command module pilot.

ASTRONAUT EDWARD WHITE II USAF

Born November 14, 1930 in San Antonio, Texas. He received a Master of Science Degree in Aeronautical Engineering from the University of Michigan in 1959 and an Honorary Doctorate from there in 1965. He was a highly decorated pilot in the Air Force and as an astronaut, earning among many other medals, the NASA Exceptional Service Medal. He was pilot on Gemini 4 and performed the first "space walk" while on that mission. He was named senior pilot for the Apollo series. Lt. Colonel White died in the Apollo spacecraft fire which also killed Roger Chaffee and Gus Grissom on January 27, 1967.

ASTRONAUT ALFRED MERRILL WORDEN USAF

Born February 7, 1932 in Jackson, Michigan. He graduated from Jackson High School and went on to the United States Military Academy at West Point where he graduated with a degree in Military Science in 1955. He received a Master of Science Degree in Astronautical/Aeronautical Engineering and Instrumentation Engineering from the University of Michigan in 1963. He was awarded an Honorary Doctorate of Astronautical Science from the University of Michigan in 1971. Worden served as a member of the support crew for Apollo IX and as a backup pilot for Apollo XII. He was command module pilot for the Apollo XV mission which landed the fourth lunar exploration crew on the moon.

---contributed by Michigan Space Center
Jackson Community College
Jackson, Michigan

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GLOSSARY

ablation	the vaporization of an outer covering used to keep the inner part cool (as on Apollo mission capsules)
abort	to cut short a mission or flight because of a malfunction
acceleration	the rate of a change in velocity over time; usually expressed in meters per second per second (m/sec ²)
aerodynamics	the science of the motion of air around or against a body like a plane or rocket and the behavior of a body moving through air
aeronautics	the science or art of designing, making and operating aircraft
aerospace	the earth's atmosphere and the space beyond
aileron	a movable hinged section on the trailing edge of the wing of an airplane used to control the rolling movements of the plane
aircraft	a machine which flies in the air supported by its own buoyancy or by the action of air over its surfaces
airfoil	a part of an aircraft (flat or curved) which is designed to keep the craft up or to control its movements through the air
airship	a self propelled, lighter than air craft which can be steered (blimp or dirigible)
airspeed	the speed of an aircraft relative to the air rather than to the ground
altimeter	device for measuring the relative altitude of an aircraft by measuring atmospheric pressure
anemometer	device for measuring the velocity of the wind
apogee	the point in an orbit farthest from the center of attraction; in an orbit about the Earth, the point farthest from the Earth

Apollo	United States program with the objective of earth-orbiting a space laboratory, launching astronauts to the vicinity of the moon, and landing a man on the moon, then returning him to earth
astro	a prefix meaning "star" or "stars" and, by extension, sometimes used as the equivalent of "celestial," as in astronautics
Astronomical Unit (AU)	a unit of distance in astronomy; the mean distance between the center of the Earth and the center of the Sun (149.6×10^6 km or 92.9×10^6 mi or 499.01 light seconds)
azimuth	the initial angle or direction between true North and a great circle course
balloon	an airtight bag filled with heated air or with a gas lighter than air so as to rise and float above the ground
bank	to incline an airplane laterally when turning
barometric pressure	the pressure of the atmosphere as indicated by a barometer
beacon	a signal light or radio transmitter emitting signals for guidance of airplanes
Bernoulli's principle	as the speed of a confined fluid increases, the fluid pressure decreases
bioastronautics	aeronautics considered for its effect upon animal life or plant life
boosters	the first stage of a multistage rocket providing thrust for the launching and the initial part of the flight
calorie (cal)	a unit of thermal energy; the energy required to raise one gram of water one degree Celsius
capsule	a small pressurized compartment for an aviator or astronaut for flight or emergency escape
ceiling	the greatest height at which an airplane can maintain level flight or operate efficiently or the base of a cloud cover
Celsius	metric measure of temperature (centigrade) (freezing = 0° ; water boils at 100°)

center of gravity	the point through which the resultant forces of gravity act no matter how the body is oriented
centrifugal force	the force that tends to impel a thing or parts of a thing outward from the center
cockpit	a space in the fuselage of an airplane for the pilot or the pilot and crew
constellation	any of 88 groups of stars forming patterns or an area of the sky covering one of those groups
contact	direct visual observation of the earth's surface made from an airplane
deceleration	negative acceleration, that is, slowing down
descent	moving from a higher level to a lower level
drag	the retarding force acting on a body (as an airplane) moving through a fluid (as air) parallel and opposite to the direction of motion
EAA	Experimental Aircraft Association
electromagnetism	the science dealing with the relationship between electricity and magnetism
elevator	a movable airfoil usually attached to the tail section of an airplane for producing a change in pitch (motion up or down)
empenage	the tail assembly of an airplane
escape velocity	the minimum velocity that a moving body (as a rocket) must have to escape from the gravitational field of the earth
exosphere	the outer fringe region of the atmosphere
extraterrestrial (ET)	from outside the Earth
FAA	Federal Aeronautics Administration
Fahrenheit	the English unit measure of temperature (freezing = 32°; water boils at 212°)
flight line	a parking and servicing area for airplanes
flight path	the path of the center of gravity of an airplane in flight

flight plan	specified information relating to the intended flight of an aircraft that is filed orally or in writing with an air traffic control facility
front (weather)	the boundary between two different air masses
fuselage	the main structure or central section of an airplane which houses the crew, passengers, cargo, etc.
g force	the force of acceleration due to gravity; at sea level on Earth, about 9.8m/S^2 or 32 feet per second per second (32 ft/Sec^2)
glide	sustained forward flight in which speed is maintained only by the loss of altitude
glider	a heavier-than-air aircraft, the free-flight of which does not depend upon a power-generating unit
gravity	the force of attraction between two bodies; the force that makes a body, if free to move, accelerate toward the center of the earth
ground speed	the speed of the aircraft relative to the ground
ground visibility	prevailing horizontal visibility near the earth's surface as reported by the National Weather Service or an accredited observer; (the average of the visibility measured N, E, S, and W)
heading	the direction in which the nose of the airplane points during flight
humidity	the measure of water vapor content in the air
hypoxia	oxygen deficiency in blood cells or tissue
inclination	the maximum angle between the plane of an orbit and a reference plane
Instrument Flight Rules	IFR - rules governing flight within the atmosphere when visibility of reference points on the ground is restricted
inertia	the tendency of a body to remain as it is, either at rest or in motion, until acted upon by some outside force

latitude	angular distance from a primary great circle or plane; on earth, the distance in degrees North or South of the Equator
light year	the distance light travels in one Earth year (5,878,000,000,000 miles)
lift	the force on an airfoil, perpendicular to the relative wind, exerted normally upward, opposing the pull of gravity
longitude	the distance in degrees of a plane through the polar axis from the prime meridian measured East and West
mass	the quantity of matter in a body
meteorology	the study of atmospheric phenomena (weather)
Newton's Laws	the three laws of motion which explain most motions of planets and satellites
orbit	to send up and make revolve in an orbit (orbit a satellite)
parabolic reflector	a curved reflective surface which brings parallel light or radio waves striking the surface to a focus point
paraglider	a flexible-winged, kite-like vehicle designed for use as a recovery system
parallax	the difference in direction of a celestial body as measured from two points on earth
perigee	the orbital point nearest the center of attraction, nearest the Earth when the Earth is the body being orbited
pitch	the blade angle of a propeller; rotation of an aircraft about the crosswise axis
radiometer	a device which detects and reacts to radiant energy
reentry	the action of reentering the earth's atmosphere after travel in space
roll	rotation about the lengthwise axis of a plane
RPM	revolutions per minute; how fast something spins

runway	a strip, either paved or improved, on which takeoffs and landings are effected
satellite	an object or vehicle which orbits the Earth, the moon, or other celestial bodies
solar cell	a device which converts solar energy striking it into electrical energy
solar system	the sun and the planets, asteroids, comets and meteors that revolve around it
spacecraft	a vehicle designed to navigate outside the atmosphere of the earth
spin	a prolonged stall in which an airplane rotates about its center of gravity while it descends
stability	the tendency of an airplane in flight to remain in straight, level, upright flight
stabilizer	the fixed airfoil of an airplane used to increase stability
stall	the flight maneuver or condition in which the air passing over and under the wings stops providing lift
standard temperature lapse rate	a temperature decrease of approximately 2° Celsius for each 1,000 feet increase in altitude
thrust	the forward force on an airplane in the air provided by the engine
torque	any turning or twisting force
track	the flight path made good over the ground by an aircraft
traffic pattern	the traffic flow that is prescribed for aircraft landing at, taxiing on, and taking off from an airport
trajectory	usually refers to the open-ended flight path of a missile as opposed to an orbit which is closed
turbulence	irregular motion of the atmosphere produced when air flows over a comparatively uneven surface

variation	the angle difference at a given point between true north and magnetic north (declination)
velocity	a measure of the rate of change in position; has the dimensions of magnitude (speed) and direction (expressed in meters per second or miles per hour for example)
venturi	a tube which has a smaller diameter in the middle than at the ends; the pressure of a fluid passing through the tube decreases and the speed increases as the diameter of the tube decreases
vertigo	sensory confusion, usually expressed as dizziness or ability to tell which way is up
visual flight rules	VFR - when weather conditions are above the minimums prescribed for visual meteorological conditions, pilots may fly with visual reference to the ground
wind sock	a cloth sleeve, mounted aloft at an airport to use for estimating wind direction and velocity
wind tee	an indicator of wind direction for takeoff and landing
wing	an airfoil whose major function is to provide lift
wing flap	a movable section of an airfoil used to change the effect of air flow over the airfoil (usually allows the plane to fly slower)
yaw	to turn about the vertical axis
zero-g	the condition of weightlessness
Zulu time	Universal time; local civil time in Greenwich, England, used throughout the world in navigation

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Authors David and Doreen Housel, extreme right, present the Elementary version of COME FLY WITH ME! in draft form to Michigan teachers at a workshop in January, 1983. Sponsored by the Aerospace Education Council, the Lake Michigan Chapter of the Ninety-Nines, Lansing Community College (LCC), and endorsed by the Department of Education, the workshop was held at LCC's Aviation Technology facility at Capital City Airport, Lansing.

ABOUT THE AUTHORS

DAVID HOUSEL

David Charles Housel, co-author, was born in Green Bay, Wisconsin on April 9, 1941, and spent his elementary education years in Ashland, Oregon; Lansing, Michigan; and Glenshaw, Pennsylvania. Graduating in 1959 from Shaler High School in Glenshaw, he returned to Oregon to study science and education at Southern Oregon College in Ashland. The year, 1967-68 was spent earning his commercial pilot's license from the Sierra Academy of Aeronautics and attending California State University at Hayward. He entered Arizona State University in 1968, graduating in 1970 with a Bachelor of Arts degree in Elementary Education. While teaching elementary school in Phoenix (1970-73), he continued graduate study at Arizona State, earning a Master of Arts degree in Science Education in 1974. He was a Graduate Teaching Assistant and Instructor at Arizona State University (1974-78) while studying for his Doctor of Philosophy degree which was granted in August, 1982. Since 1978, he has been an Assistant Professor of Education and is currently Director of the Aviation and Space Center at Oakland University in Rochester, Michigan.

DOREEN HOUSEL

Doreen Housel, co-author and illustrator, was born in Bay City, Michigan on March 30, 1939. After elementary education and high school in Unionville, Michigan, she studied first at Michigan State University and then at Wayne State University, graduating with a degree in English and Speech Education. After a move to Connecticut in 1970, she taught high school English in Stratford and, later, Advanced Expository Writing at the University of Bridgeport. Continuing her graduate studies there, she received a Masters of Arts degree in Counseling in 1978. Since 1981 she has taught at Oakland University as an Adjunct Professor, assisting with the educational television program, "Open Math." Presently she is a Doctoral candidate at Oakland University, teaching education classes and supervising student teachers.